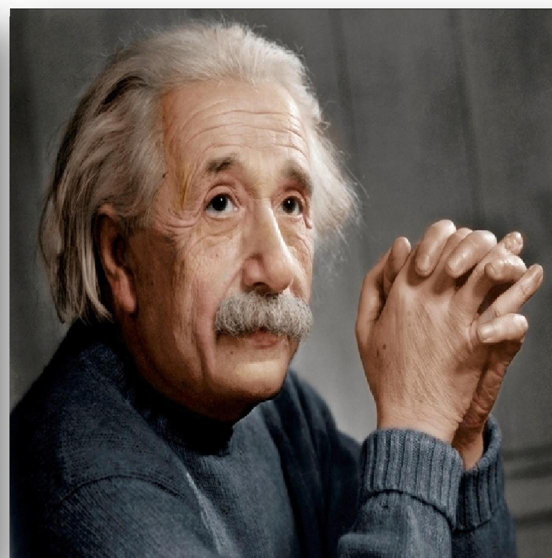
PHYSICS

INTERMEDIATE

STUDY MATERIAL

FIRST YEAR

60/60



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BOARD OF INTERMEDIATE EDUCATION

FIRST YEAR CHAPTER WISE WEIGHT OF MARKS

S.NO	NAME OF THE CHAPTER	VSAQ (2M)	SAQ (4M)	LAQ (8M)	TOTAL MARKS
1.	PHYSICAL WORLD	1	-	-	2
2.	UNITS AND MEASUREMENTS	1	-	-	2
3.	MOTION IN A STRAIGHT LINE	-	1	-	4
4.	MOTION IN A PLANE	1	1	-	6
5.	LAWS OF MOTION	1	1	-	6
6.	WORK,ENERGY & POWER	-	-	1	8
7.	SYSTEM OF PARTICLES & ROTATIONAL MOTION	2	1	-	8
8.	OSCILLATIONS	-	-	1	8
9.	GRAVITATION	-	1	-	4
10.	MECHANICAL PROPERTIES OF SOLIDS	-	1	-	4
11.	MECHANICAL PROPERTIES OF FLUIDS	2	-	-	4
12.	THERMAL PROPERTIES OF MATTER	2	1	-	8
13.	THERMODYNAMICS	-	-	1	8
14.	KINETIC THEORY	-	1	-	4
		10	32	24	76

INTER FIRST YEAR PHYSICS

	SECTION – A (2 MARKS)	10x2=20
Q. No: 1	1. Physical world	
Q. No: 2	2. Units and Measurements	
Q. No: 3	3. Motion in a Straight Line 4. Motion in a Plane	
Q. No: 4	5. Laws of Motion	
Q. No: 5	7. System of Particles and Rotational Motion 8. Oscillations	
Q. No: 6	11. Mechanical Properties of Fluids	
Q. No: 7	12. Thermal Properties of Matter 13. Thermodynamics	
Q. No: 8	12. Thermal Properties of Matter 13. Thermodynamics	
Q. No: 9	14. Kinetic Theory	
Q. No: 10	14. Kinetic Theory	
	SECTION – B (4 MARKS)	6x4=24
Q. No: 11	3. Motion in a Straight Line	
Q. No: 12	4. Motion in a Plane	
Q. No: 13	5. Laws of Motion	
Q. No: 14	7. System of Particles and Rotational Motion	
Q. No: 15	7. System of Particles and Rotational Motion	
Q. No: 16	9. Gravitation	
Q. No: 17	10. Mechanical Properties of Solids 11. Mechanical Properties of Fluids	
Q. No: 18	12. Thermal Properties of Matter 13. Thermodynamics 14. Kinetic Theory	
	SECTION – C (8 MARKS)	8x2=16
Q. No: 19	6. Work, Energy and Power	
Q. No: 20	8. Oscillations	
Q. No: 21	12. Thermal Properties of Matter 13. Thermodynamics	

IPE – MAY 2019 (TS)

I SECTION – A (10X2=20)

1. What is inertia? What gives the measure of inertia?
2. If $P = 2\hat{i} + 4\hat{j} + 14\hat{k}$ and $Q = 4\hat{i} + 4\hat{j} + 10\hat{k}$, find then magnitude of $|P+Q|$
3. Find the relative error in Z. If $Z = A^4 B^{1/3} / CD^{3/2}$
4. Arrange the fundamental force in descending order according to relative strength.
5. What is Magnus effect?
6. Give the expression for the excess pressure in a liquid drop. Mention the terms in the expression
7. Explain global warming.
8. State Newton's law of cooling.
9. When does a real gas behave like an ideal gas?
10. The absolute temperature of a gas is increased 3 times. What will be the increase in RMS velocity of the gas molecule?

II SECTION – B (6X4=24)

11. A ball is thrown vertically upwards with a velocity of 20m/s from the top of a multistory building. The height of the point from where the ball is thrown is 25m from the ground.
(a) How high will the ball rise
(b) How long will it be before the ball hits the ground? ($g = 9.8 m/s^2$)
12. Show that the trajectory of an object thrown at certain angle with the horizontal is a parabola.
13. Define terms momentum and impulse. A batsman back ball straight in the direction of the bowler without changing its initial speed of 12m/s. if the mass of the ball is 0.15kg, determine the impulse imparted to the ball. (Assume linear momentum of the ball)
14. Define angular velocity (ω). Derive $v = r\omega$.
15. What is a geostationary satellite? State its uses.
16. Find the torque of a force $7\hat{i} + 3\hat{j} - 5\hat{k}$ about the origin. The force acts on a particle whose position vector is $\hat{i} - \hat{j} + \hat{k}$
17. Define strain energy and derive the equation for the same.
18. Obtain the relation between Celsius and Fahrenheit scales of temperature. What is the temperature for which the readings on Celsius and Fahrenheit scales are same?

III SECTION – C (2X8=16)

19. Develop the notions of work and kinetic energy and show that it leads to work energy theorem
20. Show that the motion of simple pendulum is simple harmonic and hence drive an equation for its time period. What is seconds' pendulum? What is the length of a simple pendulum
21. Explain reversible and irreversible processes Describe the working of Carnot engine Obtain an expression for the efficiency.

IPE – MARCH 2019 (TS)

I SECTION – A (10X2=20)

1. What is the contribution of S. Chandra Sekher to physics?
2. Express unified atomic mass unit in kg.
3. What is the acceleration of a projectile at the top of its trajectory?
4. What happens to coefficient of friction if weight of the body is doubled?
5. What is Magnus effect?
6. What is meant by hydrostatic paradox?
7. If the maximum intensity of radiation for a black body is found at 1.45μm, what is the temperature of radiating body (When's constant = 2.9 x 10^{-3}mk)
8. Why do liquids have no linear and areal expansion?
9. When does a real gas behave like an ideal gas?
10. The absolute temperature of a gas is increased 3 times. What will be the increase in RMS velocity of the gas molecule?

II SECTION – B (6X4=24)

11. Derive $\mathbf{S = ut + \frac{1}{2}at^2}$ in graphical method.
12. O is a point on the ground chosen as origin. A body first suffers a displacement of 10 North-East, next $10\sqrt{2}$m North and finally $10\sqrt{2}$m North-West. How far it is from the origin?
13. Explain the various methods to minimize the friction.
14. What is the moment of inertia of a rod of mass M and length L about an axis perpendicular to it and passing through the one end?
15. Define vector product. Explain the properties of a vector product with two examples.
16. What is escape velocity? Obtain an expression for it.
17. Define strain energy and derive the equation for the same.
18. Pendulum clocks generally go fast in winter and slow in summer. Why?

III SECTION – C (2X8=16)

19. State the law of conservation of energy and verify it in case of a freely falling body.
Calculate the power of a pump required to lift 600kg of water per minute from a well of 25m deep.
20. Define simple harmonic motion. Show that the motion of (point) projection of a particle performing uniform circular motion, on any diameter is simple harmonic
A mass of 2kg is attached to a spring of force constant 200N/m Find its time period.
21. Explain reversible and irreversible processes Describe the working of Carnot engine Obtain an expression for the efficiency.

1. PHYSICAL WORLD

1. What is physics?

A. Study of the basic laws of nature and their manifestation in different phenomena.

2. What is the discovery of C.V. Raman.

A. C.V. Raman discovered Raman Effect. It deals with scattering of light by molecules of a medium when they are excited to vibration energy levels.

3. What are the fundamental forces in nature.

A. The fundamental forces in nature.

a) Gravitational force b) Electromagnetic force
c) Strong nuclear force d) Weak nuclear force

4. Which of the following has symmetric
a) Acceleration due to gravity
b) Law of gravitation.

A. Law of gravitation has symmetry. Because, it is same at any place in the universe.

5. What is the contribution of S. Chandra Sekher to physics?

A. He explained Chandrasekhar limits, structure and evolution of stars.

3. MOTION IN A STRAIGHT LINE

1. The states of motion and rest are relative, Explain.

A. **Rest**: - A body is said to be at rest if its position does not change with time with respect to its surroundings.
Motion: - A body is said to be in motion if its position changes with time with respect to its surroundings
Example: - The driver in a moving bus is at rest with respect to a person sitting inside the bus and he is in motion with respect to a person outside the bus.

2. How is average velocity different from Instantaneous velocity?

A. **Average velocity:** The ratio of total displacement to the total time interval is called average velocity.
Instantaneous velocity: The velocity of a particle at any instant of time is called instantaneous velocity.
Average velocity belongs to entire motion of the body.
Instantaneous velocity belongs to particular instant of time.

3. A vehicle travels half the distance L with speed V_1 and the other half with speed V_2. What is the average speed?

A. $$\text{Average speed}=\frac{\text{Total speed}}{\text{Total time}}=\frac{\frac{L}{2}+\frac{L}{2}}{t_1+t_2}$$

$$V_{avg}=\frac{L}{t_1+t_2}=\frac{L}{\frac{\left(\frac{L}{2}\right)}{V_1}+\frac{\left(\frac{L}{2}\right)}{V_2}}=\frac{L}{\left(\frac{L}{2}\right)\left(\frac{L}{V_1}+\frac{L}{V_2}\right)}=\frac{2V_1V_2}{V_1+V_2}$$

4. Give an example where velocity of an object is zero but its acceleration is not zero.

A. For a body thrown up vertically velocity is zero at the maximum height. But still acceleration due to gravity in the downward direction.

5. an object falling through a fluid is observed to have an acceleration given by a = g – bv where g is the gravitational acceleration and b is a constant. After a constant velocity. What would be the value of this constant velocity?

A. Body moves with constant velocity. We know acceleration zero i.e., a = 0.

$$\text{Given} \quad a = g - bv \Rightarrow g - bv = 0$$

$$bv = g, \quad \Rightarrow b = \frac{g}{v}$$

2. UNITS AND MEASUREMENTS

1. Distinguish between accuracy and precision.

ACCURACY	PRECISION
The degree of closeness of a measured value to its true value is called accuracy	The degree of closeness of among several measured values is called precision.
Accuracy depends on error.	Precision does not depend on errors.

2. How can systematic errors be minimized of eliminated?

A. Systematic errors can be minimized by

1) Improving experimental techniques.
2) Selecting better instruments. and
3) Removing personal bias as far as possible.

3. What are the different types of errors that can occur in a measurement?

A. The errors in measurement can be broadly classified as

a) Systematic errors and
b) Random errors.

3. What are significant figures and what do they represent when reporting the result of a measurement?

A. The digits of a number representing a measurement that are definitely known, plus one more digit added at the end which is estimated are called significant figures.
The significant figures represent the accuracy with which a physical quantity may be expressed.

4. Distinguish between fundamental units and derived units.

FUNDAMENTAL UNITS	DERIVED UNITS
The units of the fundamental physical quantities are called fundamental units.	The units of derived physical quantities are called derived untis.
Ex. Meter, Kilogram, Sec	Ex: Newton, Erg, Joule.

5. Why do we have different units for the same physical quantity?

A. We have different systems of measurements, like C.G.S and M.K.S systems. Hence we have different units for the same physical quantity.

6. Express unified atomic mass unit in kg.

A. One unified atomic mass unit = 1.66×10^{-27}kg.

7. How many orders of magnitude greater is the radius of the atom as compared to that of the nucleus?

A. The radius of a nucleus is of the order of 10^{-15} m, and that of the atom is nearly 10^{-10}m. thus 5 orders of magnitude greater is the radius of the atom as compared to that of the nucleus.

8. If the density of wood is 0.8gm/c.c. Find its value in S.I.

A. $$\text{Given density} = 0.8\text{gm/c.c} = 0.8\frac{10^{-3}\text{kg}}{10^{-6}\text{m}^3}$$

$$0.8\times10^3\,kg/m^3 = 800kg/m^3$$

$$0.8\text{gm/c.c} = 800kg/m^3$$

9. Prove that energy per unit volume is pressure.

A. $$\text{Dimensionally,}\quad \frac{\text{Energy}}{\text{Volume}}=\frac{ML^2T^{-2}}{L^3}=ML^{-1}T^{-2}$$

Dimensional formula of pressure $ML^{-1}T^{-2}$
Hence, Energy per unit volume is equal to pressure.

4. MOTION IN A PLANE

1. The vertical component of a vector is equal to its horizontal component. What is the angle made by the vector with X-axis?

A. Organ Horizontal component of vector A = vertical component of vector A.

$A_x = A_y \Rightarrow A\cos\theta = A\sin\theta \Rightarrow \tan\theta = 1.\quad \theta = 45°.$

2. A vector V makes and angle with the horizontal. The vector is rotated through an angle α. Does this rotation change the vector V?

A. Magnitude remains constant, direction changes for any value of α other than 2π, 4π, 6π _ _ _

3. A = i + j. what is the angle between the vector and X-axis?

A. $\cos\theta = \frac{A_Z}{|A|} = \frac{1}{\sqrt{1+1}} = \frac{1}{\sqrt{2}} \Rightarrow \cancel{\cos}\theta = \cancel{\cos}\,45^0, \quad \Rightarrow \theta = 45^0$

4. What is the acceleration of a projectile at the top of its trajectory?

A. At the top of the trajectory, acceleration of projectile is 'g' in downwards.

5. Two forces of magnitudes 3 units and 5 units act at 60° with each other. What is the magnitude of their resultant?

A. P = 3, Q= 5, θ = 60°

$R = \sqrt{P^2+Q^2+2P.Q.\cos\theta} = \sqrt{3^2+5^2 2(3)(5)\cos 60^0}$

$\sqrt{9+25+30.\left(\frac{1}{2}\right)} = \sqrt{9+25+15} = \sqrt{49} = \sqrt{(7)^2} = 7$

6. When two right angled vectors of magnitude 7 units and 24 units combine. What is the magnitude of their resultant?

1) P = 7, Q = 24, θ = 90° $R = \sqrt{P^2+Q^2+2P.Q.\cos\theta}$

$= \sqrt{7^2+24^2+2(7)(24)\cos 90^0} = \sqrt{49+576+0} = \sqrt{625} = \sqrt{(25)^2} = 25$

7. Can two vectors of unequal magnitude add up to give the zero vectors? Can three of the resistant vector.

A. Two vectors of unequal magnitude cannot give a zero vector by adding up. But three vectors of unequal magnitudes can give zero vectors on addition as per triangle law of vectors.

8. If $P = 2\hat{i}+4\hat{j}+14\hat{k}$ and $Q = 4\hat{i}+4\hat{j}+10\hat{k}$, find then magnitude of $|P+Q|$

A. P + Q = (2+4)i+(4+4)j+(10+14)k **=6i+8j+24k**

$|P+Q| = \sqrt{6^2+8^2+24^2} = \sqrt{36+64+576} = \sqrt{676}$

$= \sqrt{26^2} = 26$

9. Can a vector of magnitude zero have nonzero components.?

A. A vector of magnitude zero cannot have nonzero components. If a = a_xi + a_yj+ azk then its magnitude is

$a = \sqrt{A_x^Z + A_y^Z + A_z^Z}$

Here a = 0 only when a_x =0, a_y 0, a_z = 0.

10. What is meant by hydrostatic paradox?

A) The pressure of liquid is same at all points at the same horizontal level(same depth). It is called hydrostatic paradox.

5. LAWS OF MOTION

1. What is inertia? What gives the measure of inertia?

A) The inability of a body to change its state of rest (or) state of motion by itself is called inertia.
Mass is a measure of inertia.

2. When a bullets is fired from a gun, the gun gives a kick in the back ward direction. Explain.

A) 1) This is due to **law of conservation of momentum,**
2) When Bullet is fired from the gun. The bullet moves forward and so gun recoils back to balance the momentum developed by the bullet.

3. If a bomb at rest explodes into two pieces, the pieces must travel in opposite directions. Explain.

A) 1) This is due to **law of conservation of momentum,**
2) When the bomb explodes into two pieces, the two pieces must have equal and opposite momentum. So, the pieces must travel in opposite direction.
$0 = m_1v_1 + m_2v_2$, $\quad m_1v_1 = -m_2v_2$

4. Define force, what are the basic forces in nature?

A) <u>**Force**</u>: The external agency which changes (or) tries to change the state of the body is known as force.
Basic forces are 1) gravitational forces
2) electromagnetic forces 3) nuclear forces etc.

5. A horse has to pull harder during the start of the motion than later. Explain.

A) $F_S > F_K > F_R$ for starting motion of the cart, then static friction is to be overcome. This static friction is greater than kinetic friction. Hence the horse has to pull harder during start of the cart.

6. Why does the car with a flattened tire stop sooner than the one with inflated tires?

A) 1) In case of flattened tires more deformation occurs when compared to that of inflated tires. Due to more deformation of the tires the area of contact increases. Since rolling friction is directly proportional to the area of flattened tires stop sooner that of inflated tires.

7. Can the coefficient of friction be greater than one?

A. Yes, when the contact surfaces are heavily polished then the adhesive forces between the molecules increases and the value of coefficient of friction will be greater than one.

8. What happens to coefficient of friction if weight of the body is doubled?

A. Coefficient of friction is independent of weight of the body so it remains constant.

9. According to Newton's third law, every force is accompanied by an equal and opposite force. How can a movement ever take place?

A. Here action and reaction forces act on different bodies. Hence they do not cancel each other. Hence, motion of a body can be possible.

10. Why does a heavy rifle not recoil as strongly as light rifle using the same cartridges?

A. According to law of conservation momentum ,
m_1v_1 (bullet) = - m_2v_2(gun)
For same cartridge is constant

$m_2v_2 = \text{constant}\,(\text{or})\, v_2 \alpha \left(\frac{1}{m_2}\right)$

So a heavy rifle will recoil with less velocity than a light rifle using the same cartridge.

6. WORK-ENERGY-POWER

1. State the conditions under which a force does not work?

A) Work done $W = \vec{F}.\vec{S}\,Cos\theta$

1) If the displacement of a body is zero, then W = 0.
2) If the angle between the force and displacement is 90^0,then W = 0.

2. Define work, power and energy. State their SI units

A) **Work:** If an object displaces by application of force is called work. $W = \vec{F}.\vec{S}\,Cos\theta$ **SI units:** Joule.

Dimensional formula: $M^{1}L^{2}T^{-2}$

Energy: capacity to do work is called energy.

SI units: Joule. Dimensional formula: $M^1L^2T^{-2}$

Power: The rate of doing work is called power.

SI units: Watt, Dimensional formula $M^1L^2T^{-3}$

3. State the relation between the kinetic energy and momentum of a boy.

A) When a body of mass 'm' moves with a velocity 'v' an linear momentum, (P = mv)

$$KE = \frac{1}{2}MV^2 = \frac{1}{2}M\left(\frac{P}{m}\right)^2 \Rightarrow KE = \frac{P^2}{2m}$$

4. A body freely falling from a certain height 'h', after striking a smooth floor rebounds and rises to a height h/2. What is the coefficient of restitution between the floor and the body?

A) Given $h_1 = h$, $h_2 = h/2$. $e = \sqrt{\frac{h_2}{h_1}} = \sqrt{\frac{h/2}{h}} = \frac{1}{\sqrt{2}} = 0.7.7$

5. State the sign of work done by a force in the following

(a) Work done by a man in lifting a bucket out of a well means of a rope tied to the bucket.

(b) Work done by gravitational force in the above case.

A) (a) Positive. (b) Negative.

6. State the sign of work done by a force in the following

(a) Work done by an applied force on a body moving on a rough horizontal plane with uniform velocity

(b) Work done by resistive force of air on a vibrating pendulum in bringing it to rest.

A) (a) Positive. (b) Negative.

7. State the sign of work done by a force in the following

(a) Work done by friction on a body sliding down an inclined plane.

(b) Work done by gravitational force in the above case.

A) (a) Negative. (b) Positive.

8. Which of the following quantities remains constant (i) in elastic collision? (ii) in inelastic collision?

A) (i) in elastic collision momentum and kinetic energy are conserved (remains constant)

(ii) in inelastic collision only momentum is conserved.

9. What is the total displacement of a freely falling body, after successive rebounds from the same place of ground, before it comes to stop? Assume that 'e' is the coefficient of restitution between the body and the ground

A) If a body is dropped freely from a certain height 'h', the distance it travels $S = \left(\frac{1+e^2}{1-e^2}\right)h$

But the total displacement of the body is 'h'

7. SYSTEM OF PARTICLES & MOTION

1. Is it necessary that a mass should be present at the centre of mass of any system?

A) No, it is not necessary that a mass should be present at the center of mass of any system.

2. |What is the difference in the position of a girl carrying a bag m one of her hands and another girl carrying a bag in each of her two hands?

A) In the case of girl carrying a bag in each of her two hands there will be no change in the position of her centre of mass.

3. Two rigid bodies have same moment of inertia about their axes of symmetry. Of the two, which body will have greater kinetic energy?

A) Rotational KE =

Given moment of inertia is same, KE $\propto L^2$

A body of greater angular momentum will have greater kinetic energy.

4. Why are spokes provided in a bicycle wheel?

A) To reduce the jerks in the cycle, the moment of inertia is increased to maximum, possible value for minimum. Possible, weight. A large moment of inertia is obtained by putting more mass far away from axis. Thus spokes are fitted in the cycle wheel.

5. By spinning egg on a table top, how will you distinguish a hardboiled egg from a raw egg?

A) Moment of inertia of raw egg is more than boiled egg. When the same torque is applied on both eggs, boiled egg spins faster than raw egg. r = Iα, $\alpha \propto \frac{1}{I}$.

6. Why should a helicopter necessarily have two propellers?

A) 1) This is due to **Law of conservation of angular momentum**

2) If there is only one propeller, then the helicopter rotates itself in the opposite direction. That is useless

7. Why is it easier to balance a bicycle in motion?

A) The rotating wheels of bicycle possess angular momentum. In the absence of an external torque, neither the magnitude nor the direction of angular momentum change. The direction of angular momentum is along the axis of the wheel. So the bicycle does not get titled

8. Why do we prefer a spanner of longer arm as compared to the spanner of shorter arm?

A) As $\tau = r \times F$, as spanner of longer arm, can produce greater torque

9. We cannot open of close the door by applying force at the hinges. Why?

A) Opening of closing the door by applying force at the hinges is a turning effect or torque. We know $\tau = r \times F$ At the hinges r = 0, so τ = 0. Hence no turning effect.

10. What is the difference in the positions of center of mass of a girl carrying a bag in one of her hands and another girl carrying a hag in each of her two hands?

A) In case of a girl carrying a bag in one of her hands, the centre of mass of her body will shifted towards her hand in which she is carrying the bag.

In case of another girl carrying a bag in each of her two hands (mass of each hag is same) there will be no change in the position of her centre of mass.

08. OSCILLATIONS

1. Give two examples of periodic motion which are not oscillatory.

A) (i) Motion of seconds hand of a watch.
(ii) Revolution of a planet around the sun.
(iii) Revolution of an electron around the nucleus.
(iv) Revolution of the moon around the earth.

2. The displacement in S.H.M. is given by Y = a sin(20t+4). What is the displacement when 't' is increased by $2\pi / \omega$

A) Displacement does not change because after every $2\pi / \omega$ second the motion is repeating.

3. A girl seated in a swing and is swinging. What is the effect on the frequency of oscillation if she stands?

A) From time period $T = 2\pi\sqrt{\frac{l}{g}}$ and at same place $T\alpha\sqrt{l}$

and frequency $n\alpha\frac{1}{\sqrt{l}}$. If a girl sitting in a swing stands up, then centre of mass shifts up and hence length 'l' of the swing decreases. Then the time period decreases and frequency of oscillations increases.

4. What fraction of the total energy is K.E when the displacement is one half of amplitude of a article executing S.H.M?

A) $K.E = \frac{1}{2}m\omega^2(A^2-Y^2)$ $T.E = \frac{1}{2}m\omega^2A^2$, $Y = \frac{A}{2}$

$$\frac{K.E}{T.E} = \frac{\frac{1}{2}m\omega^2(A^2-Y^2)}{\frac{1}{2}m\omega^2A^2} = \frac{\frac{1}{2}m\omega^2(A^2-\frac{A^2}{4})}{\frac{1}{2}m\omega^2A^2} =$$

$$\frac{\frac{3}{4}\cancel{\left(\frac{1}{2}m\omega^2A^2\right)}}{\cancel{\frac{1}{2}m\omega^2A^2}} = \frac{3}{4}$$

Kinetic energy is 3/4 part of total energy

5. What happens to the energy of a simple harmonic oscillator if its amplitude is doubled?

$$\frac{E_2}{E_1} = \left(\frac{A_2}{A_1}\right)^2 \quad [T.E = \frac{1}{2}m\omega^2A^2]$$

$A_2 = 2A_1$

$$\frac{E_2}{E_1} = \left(\frac{2A_2}{A_1}\right)^2 = 4, \; E_2 = 4E_1$$

Energy will be increased by four times

6. Will a pendulum clock gain or lose time when taken to the top of a mountain?

A) From time period $T = 2\pi\sqrt{\frac{l}{g}}$ and at same place $T\,\alpha\,\frac{1}{\sqrt{g}}$

and $n = \frac{1}{T}$ When the pendulum is taken to the top of a mountain, acceleration due to gravity 'g' decreases, time period increase and number of oscillations per second decreases. So the number of oscillations per day also decreases. Hence it will go slow.

7. A pendulum clock gives correct time at the equator. Will it gain or lose time if it is taken to the poles? If so, why?

A. At poles the value of 'g' is more. $T = 2\pi\sqrt{\frac{l}{g}}$

So as 'g' increases, 'T' decreases. As time period (T) decreases it will make more oscillations. So the clock gains time.

9. GRAVITATION

1. ** **What is the time period of revolution of a geostationary Satellite? Does it rotate from west to east or east to west?**

A) Time period of revolution of a geostationary satellite is 24 hours from west to east.

2. ** **What are polar satellites?**

A) Satellites which go around the poles of the earth in North and south direction are called polar satellites.

3. Hydrogen is in abundance around the sun but not around earth explain.

A) The escape velocity of sun is greater than r.m.s velocity hydrogen. But the escape velocity of earth is less than r.m.s velocity hydrogen. So hydrogen is in abundance around the sun.

4. State the units and dimensional formula of universal gravitational constant.

A. D.F of U.G.C is $\left[M^{-1}L^3T^{-2}\right]$ and its unit $\left(N-m^2/kg^2\right)$

5. If gravitational force of the earth of the moon is F. what is the gravitational force of the moon on the earth? Do these forces from an action –reaction pair?

A. The gravitational force of moon on earth is also 'F'. Yes, they form action and reaction pair.

6. * **What would be the change in acceleration due to gravity(g) at the surface, if the radius of earth decreases by 2% keeping the mass of earth constant?**

A. $g\alpha R^{-2}$ $\frac{\Delta g}{g}\times 100\% = -2\frac{\Delta R}{R}\times 100\%$

$= -2(-2\%) = 4\%$

g *increases by* 4%

7. As we go from one planet to another planet, how will (a) the mass and (b) weight of a body changes?

A. a) The mass of a body is constant.
b) Weight of a body first decreases gradually with height, becomes zero and again increases due to gravitational field of another planet.

8. keeping the length of a simple pendulum constant, will the time period be the same on all planets? Give the reason?

A. No. From $T = 2\pi\sqrt{\frac{l}{g}}$ as 'g' changes from planet to planet and time period 'T' also changes.

9. Give the equation for the value of 'g' at depth 'd' from the surface of earth. What is the value of 'g' at the centre of earth

A. a) $g_d = g\left(1-\frac{d}{R}\right)$

b) d = R at the centre of earth $g_d = g\left(1-\frac{d}{R}\right) = 0$

10. What are the factors that make 'g' the least at the equator and maximum at the poles?

A) From $g = \frac{GM}{R^2}$ for the earth, we have $g\,\alpha\,\frac{1}{R^2}$

As the radius of the earth is maximum along the equator, 'g' is minimum at the equator.
As the polar radius of the earth is minimum, 'g' is maximum at the poles.

11. MECHANICAL PROPERIES OF FLUIDS

1. ** **Define Viscosity. What are its unit and dimensions?**

A) **Viscosity**: The property of a fluid which opposes the relative motion between different layers in contact is called viscosity.
S.I units: Poiseiulle (or) Pascal. **D.Formula:$M^1L^1T^{-1}$**

2. ** **What is the principle behind the carburetor of an automobile?**

A) The carburetor of an automobile works on Bernoulli's principle
Working: It has a nozzle in which air flows with large speed. So the pressure is lowered at the nozzle and petrol flows from the chamber to nozzle at low pressure and provide correct mixture of air to fuel for combustion.

3. ** **What is Magnus effect?**

A) When the ball is spinning and moving in the air, it experience a net upward force called dynamic lift. This dynamic lift due to spinning is called 'Magnus effect'

4. ** **Why are drops and bubbles spherical?**

A) 1) Due to **surface tension,** rain drops and water Bubbles are spherical in nature.
2) For a given volume, **sphere has minimum surface area.** So liquid drops and Bubbles are spherical.

5. ** **Give the expression for the excess pressure in the soap bubble in air, Mention the terms in the expression.**

A) Excess pressure in soap bubble $P = \frac{4T}{r}$
Where 'r' radius of bubble. 'T' surface tension.

6. ** **Give the expression for the excess pressure in a liquid drop. Mention the terms in the expression**

A) Excess pressure in liquid drop $P = \frac{2T}{r}$
Where 'r', radius of bubble. T surface tension

7. * **What are water proofing agents and water wetting agents? What do they do?**

A) **Water proofing agents** increase the angle of contact.
Example: - Wax
Water wetting agents reduces the angle of contact.
Example: - Soaps, detergents.

8. * **What is angle of contact?**

A) The angle between the tangent to the liquid surface and solid surface, at the point of contact, inside the liquid is known as angle of contact.
Its value pure water is 0^0, its value for pure mercury is 140^0

9. When water flows through a pipe, which of the layers moves fastest and slowest?

A) The layer at the centre of pipe moves fastest. The layer of the liquids in contact with the fixed surface is slower

10. Define surface tension. Write its units and dimensional formula.

A) The tangential force acting per unit length of an imaginary line drawn on the liquid surface is called surface tension $T = \frac{F}{l},\ S.I\,Units: Nm^{-1},\ D.F\,is = [MT^{-2}]$

11. Define streamline flow & turbulent flow ?

A) **Streamline flow:** In a fluid flow, if the velocity of all the particles passing through the same point is constant then the flow is called streamline flow.
Turbulent flow: In a fluid flow, if the velocity of different particles passing the same point is different then the flow is called turbulent flow.

13. THERMODYNAMICS

1. Define Calorie? What is the relation between calorie and mechanical equivalent of heat?

A) **Calorie**: The amount of beat required to raise the temperature of one gram of water from 14.5°C to 15.5°C at atmosphere pressure is called Calorie.
1 Caloric: 4.186 joule.

2. What thermodynamic variables can be defined by (a) Zeroth law (b) first law

A) (a) Zeroth law defines a property of **matter** is called temperature
(b) First law defines a property of **system** is called Internal energy

3. Why a heat engine with 100% efficiency can never be realized in practice?

A) It is because $\eta = \left(1 - \frac{T_2}{T_1}\right)$ and
It is impossible to make T_2 = °K (or) $T_1 = \propto$ K

4. In summer, When the value of a bicycle tube is opened, the escaping air appears cold. Why?

A) When the value from a cyclic tube is removed, the air inside it expands adiabatically and as such becomes cool.

5. While does the brake drum of an automobile get heated up while moving down at constant speed?

A) The brake drum of an automobile for constant speed. As a result of friction between wheel and its brake drum then temperature of brake drum increases.

6. A thermos flask containing liquid is shaken vigorously. What happen to its temperature?

A) As work is done on the system internal energy increases and there is slight increase in the temperature of the liquid

7. Can a room be cooled by leaving the doors of an electric refrigerate open?

A) No, the not cool by opening the door of refrigerator, refrigerator absorbs heat from cold reservoir and rejects more heat surroundings. Hence it cannot be cooled the room

8. How much will be the internal energy change in i)Isothermal process ii) adiabatic process .

A) There is no change in the inland energy of an ideal gas in an isothermal process. AU = 0 For adiabatic process AU = -AW Work done by the gas results in decrease in its internal energy. If work is done on the gas then its internal energy increases.

10. Why is it easier to perform the skating on the snow?

A) Skating is possible on snow due to the formation of water below the skates. Water is formed lower temperature due to the increase of pressure and it acts as lubricant.

12. Define absorptive power of a body. What is the absorptive power of a perfect black body?

A) The ratio of the radiant energy absorbed per seconds by unit surface area of the body, to the total energy incident per second on the same area is called absorptive power on the same body. Absorptive power of a perfectly black body is equal to 1.

13. State the law of equipartition of energy

A) The total energy is equally distributed in all possible energy modes, with each mode having an average energy is equal to $\frac{1}{2}K_BT$ that is known as the law of equipartition of energy

12. THERMAL PROPERTIES OF MATTER

1.* Distinguish between heat and temperature

HEAT	TEMPERATURE
Heat is form of energy which flows from one point to another is called heat.	Temperature is form of energy which is measure of the degree of hotness or coldness of a body.
C.G.S Units: **Calorie.**	C.G.S Units: ^{0}C.
M.K.S Units: **Joule.**	M.K.S Units: Kelvin.

2. Do the values of coefficients of expansion differ when the temperatures are measured on centigrade scale or on Fahrenheit scale?

A) Yes, one degree interval on Fahrenheit scale is less than one degree interval on Celsius scale $1^0F= 5/9\ ^0C$

3.* Can substance contract on heating? Give an example.

A) Yes. Some substance contact on heating
Ex: Cast iron, Indian Rubber, Type metal.

4. Why gaps are left between rails on a railway track?**

A) 1) In the construction of railway track, a small gap is to be left between the ends of two successive rails.
2) This is to **allow 'linear expansion'** during in summer.

5. Why do liquids have no linear and Areal expansions?

A) Liquids have no shape of their own. They always take shape of the container. Liquids are not measured in length wise and area wise so liquids have no Linear and Areal expansion.

6. What is specific gas constant? Is it same for all gases?

A) The universal gas constant per unit mass is called specific gas constant r=R/M, No. It is not same for all gases. It is different for different gases.

7. What are the units and dimensions of specific gas constant?

A) C.G.S units. **Cal gm^{-1} C^{-1}**, SI units: **J Kg^{-1}K^{-1}**
Dimensional formula: **M °L^{2}T^{-2}K^{-2}**

8.* Why utensils are coated black? Why the bottom of the utensils is made up of copper?

A) Black color is a good absorber and good emitter. In order to absorb more heat energy the outside of the utensils are coated black.
The bottom of the utensils are made of copper because copper is good conductor of heat. Copper conducts the distribution of heat at the bottom of vessel for uniform cooking.

9. Sate wien's displacement law?

A) The wave length (λ_m) for which energy is maximum is inversely proportional to absolute temperature of the body. $\lambda_m \alpha \frac{1}{T} (or) \lambda_m T = constant$
The value of constant (wine's constant) is 2.9 x10^{-3} mK

10.* Ventilators are provided in rooms just below the roof. Why?

A) 1)Hot air has less density. So it moves upwards due to **'Convection'**.
2)To escape this hot air outoff the room, ventilators are provided just below the roof.

11. Does the body radiate heat at 0^{0}K? Does it radiate heat 0^{0}C?

A) No, the body does not radiate heat at 0^{0}K
Yes, the body radiates heat at 0°C

12. The roof of buildings is often painted, white during summer. Why?

A) 1) White paint is a **good reflector of heat** and is **bad absorber of heat**.
2) So buildings that are painted white to **keep cool during summer**.

13. What is green house effect? Explain global warming?

A) Greenhouse effect: the greenhouse effect is a process by which thermal radiation from earth's surface is absorbed by atmospheric greenhouse gases (carbon dioxide, methane, nitrous oxide) and is radiated in all directions. Since part of this re-radiation is back towards the surface and the lower atmosphere, it results in heating up of earth's surface and atmosphere.

14. Define emissive power and emissivity.

A) The energy radiated by the body per second per unit area at a given wavelength and temperature is called **'emissive power'** of the body.
The ratio of the emissive power of the body to that black body at the same temperature is called **emissivity**.

15. What is latent heat of vaporization?

A) The amount of heat required to convert unit mass of a substance from liquid state to gaseous state at constant temperature is called latent heat of vaporization.
Ex: - Latent heat of vaporization of water is 540cal/gram.

14. KINETIC THEORY OF GASES

1. Define mean free path.

A) The average distance covered by a molecule between two successive collisions is called mean free path

$$\text{Mean Free Path} = \frac{1}{\sqrt{2}n\pi d^2}$$

2. Name two prominent phenomena which provide conclusive evidence of molecular motion

A) i) Dalton law 2) Avogadro law

3. When a real gas does behave like an ideal gas?

A) At low pressure and high temperature real gas behaves like an ideal gas.

4. State Dalton's law of partial pressures

A) The total pressure of a mixture of ideal gases is the sum of partial pressures is called Dalton's law of partial pressures. $P=P_1+P_2+P_3+P_4$---------

5. What is the expression between pressure ad kinetic energy of a gas molecule?

A) We know that P= 2/3 NR/V where K is the average kinetic energy of translation per gas molecule. N is number of molecule, V is volume of the gas

6. Pressure of an ideal gas in container independent of shape of the container explain

A) The pressure of an ideal gas in container =1/3 mnV^2
This pressure is independent of A and Δ t. By pascal's law. Pressure in one portion of the gas in equilibrium is the same as anywhere else. Hence pressure of an ideal gas in container is independent of shape of the container

8. What is beta decay? Which force is a function of it?

A) The nucleus emits an electron an electron and an uncharged particle called nutrition. This process is called beta decay. Weak nuclear force is function of it.

9. The coolant in a chemical or a nuclear plant should have specific heat. Why?

A. Because more heat developed in nuclear plant this heat can observed by coolants like heavy water.

1. Calculate percentage error in the error determination of $g = 4\pi^2 \frac{L}{T^2}$ when, 'L' and 'T' are measured with $\pm 2\%$ and $\pm 3\%$ error respectively

A) $g = 4\pi^2 \frac{L}{T^2}$ $\frac{\Delta g}{g}\times 100 = \pm\left(\frac{\Delta L}{L}\times 100 + \frac{2\Delta T}{T}\times 100\right)$

$= \pm\left(2 \pm (2\times 3)\right) = \pm(2\pm 6) = \pm 8\%$

2. The pressure on a circular plate is measured by measuring the force on the plate and the radius of plate. If the errors in measurement of the force and radius are 5% and 3% respectively find the percentage of error in the measurement of pressure?

A) $\Pr essure = \frac{Force}{Area}; P = \frac{F}{A} = \frac{F}{\pi R^2}$

$\frac{\Delta P}{P}\times 100 = \frac{\Delta F}{F}\times 100 + \frac{2\Delta R}{R}\times 100$

$= 5 + 2(3) = 5 + 6 = 11\%$

3. What is error in density of a cube when its mass is Uncertainty by $\pm 2\%$ and length of its edge is uncertainty by $\pm 1\%$?

A) $Density\,(\rho) = \frac{M}{V} = \frac{M}{L^3}$ $\frac{\Delta\rho}{\rho} = \frac{\Delta M}{M} + 3\frac{\Delta L}{L}$

$= \pm(2\% + 3\times 1\%) = \pm 5\%$

4. A physical quantity X is related to four measurable quantities a,b,c, and d as follows $X=a^2 b^3 c^{5/2} d^{-2}$. The percentage error in the measurement of a,b,c and d are 1%,2%,3% and 4%. What is the percentage error in X? Given that $X=a^2b^3c^{5/2}d^2$ the maximum percentage error in the measurement of quantity X is

A) $\frac{\Delta X}{X}\times 100 = 2\left(\frac{\Delta a}{a}\times 100\right) + 3\left(\frac{\Delta b}{b}\times 100\right) + \frac{5}{2}\left(\frac{\Delta c}{c}\times 100\right) + 2\left(\frac{\Delta d}{d}\times 100\right)$

Given that the percentage error in the measurement of quantities a,b,c and are1%,2%,3%and4%respectively

$\therefore \frac{\Delta X}{X}\times 100 = 2(1\%) + 3(2\%) + \frac{5}{2}(3\%) + 2(4\%)$

=2%+6%+7.5%+8%=23.5%

5. The temperature of two bodies measured by a thermometer are $t_1=20^0C\pm 0.5^0C$ and $t_2=50^0C\pm 0.5^0C$. Calculate the temperature difference and the error there in

A) $t' = t_2 - t_1 = \left(50^0 C \pm 0.5^0 C\right) - \left(20^0 C \pm 0.5^0 C\right)$

$\Rightarrow t' = 30^0 C \pm 1^0 C$

6. Find the relative error in Z. If $Z=A^4 B^{1/3}/ CD^{3/2}$ The relative error in Z is

A) $\frac{\Delta Z}{Z} = 4\left(\frac{\Delta A}{A}\right) + \left(\frac{1}{3}\right)\left(\frac{\Delta B}{B}\right) + \left(\frac{\Delta C}{C}\right) + \left(\frac{3}{2}\right)\left(\frac{\Delta D}{D}\right)$

7. The resistance R= V/I where $V = (100 \pm 5\%)V$ and $I = (10 \pm 2\%)A$. Find the percentage error in R.

A) $\frac{\Delta R}{R}\times 100 = \frac{\Delta V}{V}\times 100 + \frac{\Delta I}{I}\times 100$

The percentage error in V is 5 and in I is 2. Therefore, the total error in R would be 5+2=7%

8. The period of oscillations of a simple pendulum is $T = 2\pi\sqrt{L/g}$. Measured value of L is 20.0 cm known to 1mm accuracy and time for 100 oscillations of the pendulum is found to be 90s using a wrist watch of 1s resolution. What is the accuracy in the determination of g?

A) $g = 4\pi^2 \frac{L}{T^2}$

Here, $T = \frac{t}{n}$ and $\Delta T = \frac{\Delta t}{n}.Therefore, \frac{\Delta T}{T} = \frac{\Delta t}{t}$

The errors in both L and t are the least count errors.

Therefore, $\left(\frac{\Delta g}{g}\right) = \left(\frac{\Delta L}{L}\right) + 2\left(\frac{\Delta T}{T}\right) = \frac{0.1}{20.0} + 2\left(\frac{1}{90}\right) = 0.027$

Thus, percentage error in g is

$(\Delta g/g)100 = (\Delta L/L)100 + 2\times(\Delta T/T)100 = 2.7$

9. The measured mass and volume of a body are 2.42 g and 4.7 cm^3 respectively with possible errors 0.01 g and 0.1 cm^3. Find the maximum error in density

A) $Density = \frac{mass}{volume}$ Maximum percentage error in density

$= \frac{\Delta m}{m}\times 100 + \frac{\Delta V}{V}\times 100 = \left(\frac{0.01}{2.42}\times 100 + \frac{0.1}{4.7}\times 100\right)$

=0.413+2.127=2.54%

10. The error in measurement of radius of a sphere is 1%. What is the error in the measurement of volume?

A) **We know** $V \propto r^3$

So, $\frac{\Delta V}{V}\times 100 = 3\frac{\Delta r}{r}\times 100$ **But given** $\frac{\Delta r}{r}\times 100 = 1\%$

Hence, $\frac{\Delta V}{V}\times 100 = 3(1) = 3\%$

11. The percentage error in the mass and speed are 2% and 3% respectively. What is the maximum error in kinetic energy calculated using these quantities?

A) $K = \frac{1}{2}mv^2 \Rightarrow K \propto mv^2$

$\frac{\Delta K}{K}\times 100 = \left(\frac{\Delta m}{m}\times 100\right) + 2\left(\frac{\Delta v}{v}\times 100\right)$

Given $\frac{\Delta m}{m}\times 100 = 2\%\, and\, \frac{\Delta v}{v}\times 100 = 3\%$

$\frac{\Delta K}{K}\times 100 = 2 + 2(3) = 8\%$

11. The velocity of a body is given by $V = At^2 + Bt + C$. If V and t are expressed in S.I units what are units of A, B & C?

Given $V = At^2 + Bt + C$

According to principle of homogeneity

1) $V = At^2 \Rightarrow A = \frac{V}{t^2} = \frac{LT^{-1}}{T^2} = \left[LT^{-3}\right] \Rightarrow A = ms^{-3}$

2) $V = Bt \Rightarrow B = \frac{V}{t} = \frac{LT^{-1}}{T} = \left[LT^{-2}\right] \Rightarrow B = ms^{-2}$

3) $V = C \Rightarrow C = LT^{-1} \Rightarrow C = ms^{-1}$

3. Motion in a straight line (4 Marks)

1. Show that the maximum height reached by a projectile launched at an angle of 45^0 is one quarter of its range

A) In case of a projectile thrown at angle $\theta = 45^0$ with an initial velocity 'u'

$$H_{max} = \frac{u^2\sin^2\theta}{2g} = \frac{u^2}{2g}\left(\sin 45^0\right)^2 = \frac{u^2}{2g}\left(\frac{1}{\sqrt{2}}\right)^2 = \frac{1}{4}\frac{u^2}{g}$$

$$R_{max} = \frac{u^2\sin 2\theta}{g} = \frac{u^2\sin\left(2\times 45^0\right)}{g} = \frac{u^2}{g}\sin\left(90^0\right) = \frac{u^2}{g}$$

$$\boxed{H_{max} = \frac{R_{max}}{4}}$$

Thus, Maximum height is one quarter of the Range.

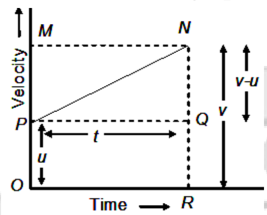
2. Derive $S = ut + \frac{1}{2}at^2$ in graphical method.

A) Let a body moving with an initial velocity u, uniform acceleration a along a straight line after t second its gain velocity and S displacement S= area of under V-t graph

$S = \text{Area of}\left(\square OPQR + \Delta PQN\right)$

$S = (OP)(PQ) + \frac{1}{2}(PQ)(QN)$

$S = \left(u\times t\right) + \left(\frac{1}{2}t\left(v-u\right)\right)$



$\boxed{S = ut + \frac{1}{2}at^2}$ $\qquad (\because v-u = at)$

3. A particle moves in a straight line with uniform acceleration. Its velocity at time t = 0 is V_1 and at time t = t is V_2. The average velocity of the particle in this time interval is $(V_1 + V_2)/2$. Is this correct? Substantiate your answer.

A) Yes, it is correct

Consider a particle moving with uniform acceleration 'a' along a straight line (say x – axis).

$$V_{avg} = \frac{\text{Total Displacement}}{\text{Total Time}} = \frac{S}{t}\text{..........(1)}$$

$$V_{avg} = \frac{\left(\frac{V_2^2 - V_1^2}{2\cancel{a}}\right)}{\left(\frac{V_2 - V_1}{\cancel{a}}\right)} \qquad \therefore \left(s = \frac{v^2 - u^2}{2a} \text{ and } t = \left(\frac{v-u}{a}\right)\right)$$

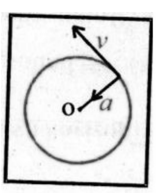
$$V_{avg} = \frac{\left(V_2 + V_1\right)\left(V_2 - V_1\right)}{\left(V_2 - V_1\right)2} = \frac{\left(V_2 + V_1\right)}{2}$$

average velocity of the particle equal to $\frac{V_1 + V_2}{2}$

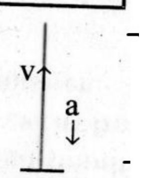
4. Can the velocity of an object be in a direction other than the direction of acceleration of the object? If so, give an example.

A) Yes,

1) For a particle moving in uniform circular Motion, its velocity along the tangent Drawn to it. But acceleration is directed to wards its centre.



2) For a body projected vertically upwards Before reaching the highest point, its Velocity is directed vertically up wards. But acceleration is in downward direction.



5. A parachutist flying in an aero plane jumps when it is at a height of 3km above ground. He opens his parachute when he is about 1km above ground. Describe his motion

A. Motion before parachute open.

1. With velocity '**v**' of aero plane, he moves horizontally Through $x = vt$

2. Due to gravity he moves vertically downwords $y = \frac{1}{2}gt^2$

So he follows a parabolic path w.r.t ground till he opens the parachute.

Motion after Parachute open: In upward direction due to air **1)** viscous. **2)** Buoyant forces act. In downward direction gravitational force act.

Due to these forces the net acceleration will become zero after falling through certain height, from there he moves along straight line with constant velocity called terminal velocity till reaches the ground.

6. A typical raindrop is about 4mm in diameter. If a raindrop falls from a cloud which is 1km above the ground, estimate its momentum when it hits the ground.

A) $P = (m)(v)$,Mass $m = (V)(d) = \frac{4}{3}\pi r^2\rho$

$v = \sqrt{2gh}, \quad \therefore P = \frac{4}{3}\pi r^2\rho\sqrt{2gh}, \; r = \frac{4mm}{2} = 2mm = 2\times10^{-3}m$

$\rho = 10^3 kg/m^3, \; g = 9.8 m/s^2, \; h = 10^3 m$

$\therefore P = \frac{4}{3}\times\frac{22}{7}\times(2\times10^{-3})^3\times10^3\times\sqrt{2\times9.8\times10^3}$

$= \frac{4}{3}\times\frac{22}{7}\times 8\times10^{-16}\times14\times10 \; = 0.00469 \text{ kg ms}^{-1}$

7. A man walks on a straight road from his home to a market 2.5 km away with a speed of 5km h^{-1}. Finding the market closed, he instantly turns and walks back home with a speed of 7.5 km h^{-1}. What is the (a) magnitude of average velocity and (b) average speed of the man over the time interval 0 to 50 in.

A) Time taken to go from home to market is

$t_1 = \frac{S}{V_1} = \frac{2.5}{5} \Rightarrow t_1 = \frac{1}{2}hr = 30\,min$

Time taken by him to get back from market to home is

$t_2 = \frac{S}{V_2} = \frac{2.5}{7.5} = \frac{1}{3}hr = 20\,min$

(a) average velocity $= \frac{\textit{total displacement}}{\textit{total time}} = \frac{0}{50} = 0$

$Speed_{avg} = \frac{\text{total distance}}{\text{total time}} = \frac{2.5+2.5}{\left(\frac{1}{2}+\frac{1}{3}\right)} = 6 \text{ kmph}$

8. A car travels the first third of a distance with a speed of 10 kmph, the second third at 20 kmph and the last third at 60 kmph. What is its mean speed over the entire distance?

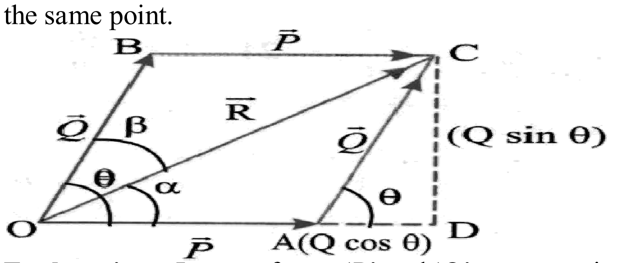
A) Given $V_1 = 10$ km/h, $V_2 = 20$ km/h and $V_3 = 60$ km/h

$$V_{avg} = \frac{3V_1V_2V_3}{V_1V_2 + V_2V_3 + V_3V_1}$$

$$V_{avg} = \frac{3(10)(20)(60)}{(10\times20)+(20\times60)+(60\times10)} = \frac{36,0\cancel{00}}{20\cancel{00}} = 18\text{kmph}$$

1. State Parallelogram law of vectors. Derive an expression for the magnitude and direction of the resultant vector.

A. **Statement:-** If two vectors are represented in magnitude and direction by the two adjacent sides of a parallelogram drawn from a point, then their resultant is represented in magnitude and direction by the diagonal passing through the same point.



Explanation:- Let two forces 'P' and 'Q' act at a point 'O'. Let 'θ' be the angle between two forces. Let the side OA = P and OB = Q. The parallelogram OACB is completed. The points 'O' and 'C' are joined. Now OC = R.

Magnitude of the Resultant vector R: - In triangle COD

$OC^2 = (OD)^2 + (CD)^2$

$OC^2 = (OA + AD)^2 + (CD)^2 \quad (\therefore OD = OA + AD)$

$OC^2 = (OA)^2 + (AD)^2 + 2(OA)(AD) + (CD)^2$

$\left(\text{From } \Delta^{le} CAD, AD^2 + CD^2 = AC^2\right)$

$OC^2 = (OA)^2 + (AC)^2 + 2(OA)(AD)$

$\left(\begin{array}{l}\text{From } \Delta^{le} CAD, \cos\theta = \dfrac{AD}{AC} \\ AD = AC\cos\theta\end{array}\right)$

$OC^2 = (OA)^2 + (AC)^2 + 2(OA)(AC)\cos\theta$

$$\boxed{R = \sqrt{P^2 + Q^2 + 2PQ.\cos\theta}}$$

Direction of the Resultant: - Let the resultant R makes an angle 'α' with the direction of A.

$\tan\alpha = \dfrac{CD}{AD} \Rightarrow \tan\alpha = \dfrac{CD}{OA + AD}$

$\left(\begin{array}{ll}\text{In } \Delta^{le} CAD, \ \sin\theta = \dfrac{CD}{AC}, & CD = AC\sin\theta \\ \text{In } \Delta^{le} CAD, \ \cos\theta = \dfrac{AD}{AC}, & AD = AC\cos\theta\end{array}\right)$

$\tan\alpha = \left(\dfrac{Q\sin\theta}{P + Q\cos\theta}\right)$

$$\boxed{\alpha = \tan^{-1}\left(\dfrac{Q\sin\theta}{P + Q\cos\theta}\right)}$$

2. If $|\vec{a} + \vec{b}| = |\vec{a} - \vec{b}|$ prove that the angle between $\vec{a}$ and $\vec{b}$ is 90^0.

Let 'θ' be the angle between $\vec{a}$ and $\vec{b}$

$|\vec{a} + \vec{b}| = |\vec{a} - \vec{b}|$

$\sqrt{a^2 + b^2 + 2ab\cos\theta} = \sqrt{a^2 + b^2 - 2ab\cos\theta}$

Squaring on both sides

$a^2 + b^2 + 2ab\cos\theta = a^2 + b^2 - 2ab\cos\theta$

$4ab\cos\theta = 0$

$\cos\theta = 0 \Rightarrow \theta = 90^0$

Hence angle between the two vectors is 90^0.

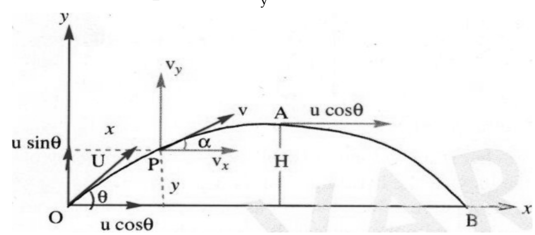
3. Show that the trajectory of an object thrown at certain angle with the horizontal is a parabola.

A When a body is projected into air at an angle 'θ' less than 90^0 to the horizontal. It is called projectile.

Consider a body projected into air with an initial velocity 'U' making an angle 'θ' with the horizontal. 'O' is the point of projection 'θ' is the angle of projection. Initial velocity 'U' can be resolved into two rectangular components.

Horizontal component $u_x = u\cos\theta$

Vertical component $u_y = u\sin\theta$



Along horizontal direction:-

Initial velocty$(u_x) = u\cos\theta$, acceleration$(a_x) = 0$

distance travelled $(S) = x$, time$(t) = t$

From $S = ut + \frac{1}{2}at^2$

$x = (u\cos\theta)t + 0$

$t = \left(\dfrac{x}{u\cos\theta}\right) ------ (1)$

Along vertical direction:-

Initial velocty$(u_y) = u\sin\theta$, acceleration$(a_x) = -g$

distance travelled $(S) = y$, time$(t) = t$

From $S = ut + \frac{1}{2}at^2 ----- (2)$

Substituting (1) in (2)

$Y = (u\sin\theta)\left(\dfrac{x}{u\cos\theta}\right) - \dfrac{1}{2}g\left(\dfrac{x^2}{u^2\cos^2\theta}\right)$

$Y = (\tan\theta)x - \left(\dfrac{g}{2u^2\cos^2\theta}\right)x^2$

$\left[\begin{array}{l}\text{Let } A = (\tan\theta), \quad B = \left(\dfrac{g}{2u^2\cos^2\theta}\right) \\ \text{where A and B are constants}\end{array}\right]$

$$Y = Ax - Bx^2$$

This is an equation for a parabola

4. A force $2\hat{i} + \hat{j} - \hat{k}$ Newton acts on a body which is initially at rest. At the end of 20 seconds the velocity of the body is $4\hat{i} + 2\hat{j} - 2\hat{k}\ m.s^{-1}$. What is the mass of the body?

A. $\vec{F} = 2\hat{i} + \hat{j} - \hat{k}$, $\vec{v} = 4\hat{i} + 2\hat{j} - 2\hat{k}$ m/s,

$u = 0$m/s, $t = 20$s, $m = ?$

Force acting on a body $\vec{F} = m\vec{a} = m\left(\dfrac{\vec{v} - \vec{u}}{t}\right)$

$(2\hat{i} + \hat{j} - \hat{k}) = m\left(\dfrac{(4\hat{i} + 2\hat{j} - 2\hat{k}) - (0)}{20}\right)$

$(\cancel{2\hat{i} + \hat{j} - \hat{k}}) = m\ \dfrac{2}{20}(\cancel{2\hat{i} + \hat{j} - \hat{k}})$

$m = \dfrac{\cancel{20}}{\cancel{2}} = 10kg$

5. Show that the maximum height and range of a projectile are $\left(\frac{u^2\sin^2\theta}{2g}\right)$ and $\left(\frac{u^2\sin 2\theta}{g}\right)$ respectively where the terms have their regular meanings.

A. **Maximum height(H):-** The maximum vertical displacement of a projectile during its journey is called maximum height

Initial velocity $(u_y) = u\sin\theta$, Final velocity$(v_y) = 0$

acceleration$(a_y) = -g$, displacement(S) = H_{max}

According to $v^2_y - u^2_y = 2a_y S$

$$S = \frac{v^2_y - u^2_y}{2a}$$

$$H_{max} = \frac{(0)^2 - (u\sin\theta)^2}{2g}$$

$$\boxed{H_{max} = \left(\frac{u^2\sin^2\theta}{2g}\right)}$$

Horizontal range(R):- The maximum horizontal displacement of a projectile where it reaches the horizontal plane of projection is called horizontal range.

Initial horizontal velocity$(u_x) = u\cos\theta$, acceleration$(a_x) = 0$,

distance = (R), Time of flight(T) = $\frac{2u\sin\theta}{g}$

Range (R) = (Horizontal velocity) (Time of flight)

$$R = (u\cos\theta)\left(\frac{2u\sin\theta}{g}\right)$$

$$\boxed{R = \left(\frac{u^2\sin 2\theta}{g}\right)} \quad [\therefore 2\sin\theta\cos\theta = \sin 2\theta]$$

Maximum horizontal range:- when a projectile is thrown at an angle 45^0 with the horizontal the range becomes maximum.

$$R_{max} = \left(\frac{u^2\sin 2\theta}{g}\right) = \frac{u^2\sin(2\times 45^0)}{g} = \frac{u^2}{g}$$

6. Show that a boat must move at an angle of 90^0 with respect to river always in order to cross the river in a minimum time?

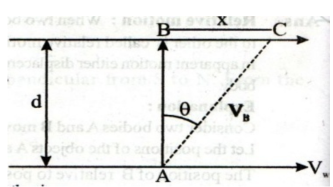
A. Suppose a river is flowing with a constant velocity V_w as shown in the figure.

Consider a boat crossing the river with velocity V_B along AC as shown in figure

The component of velocity of the boat along AB (or) normal to the river is $V_B\cos\theta$

$$\text{The time taken} = \frac{\text{width of the river}}{\text{Component of velocity of the boat along AB}}$$

$$t = \frac{d}{V_B\cos\theta}$$



$V_B\cos\theta$ must be maximum to cross the river in minimum time. $\cos\theta = 1 \,(or)\, \theta = 0^0$

Result:- To cross the river in minimum time, the boat must be rowed normal to the river flow.

7. What is relative motion? Explain it.

A. **Relative motion: -** when two bodies are moving with each other, the motion of one body with respect to another body is called relative motion. It is also called apparent motion.

Case-i) Suppose the two objects A and B are moving with the velocities V_A and V_B in the **same** direction at time't' as shown in the figure

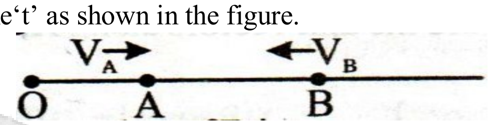
The apparent velocity of 'A' relative to that of 'B' is,

$\vec{V}_{AB} = \vec{V}_A - \vec{V}_B$ and $V_{AB} = \sqrt{V_A^2 + V_B^2 - 2V_AV_B\cos 0^0} = V_A - V_B$

Similarly, the apparent velocity of B relative to that of A is

$\vec{V}_{BA} = \vec{V}_B - \vec{V}_A$ and $V_{BA} = \sqrt{V_B^2 + V_A^2 - 2V_BV_A\cos 0^0} = V_B - V_A$

Case –ii) suppose the two objects A and B are moving with the velocities V_A and V_B in the **opposite** direction at time't' as shown in the figure.



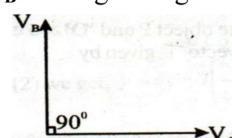
The apparent velocity of 'A' relative to that of 'B' is,

$\vec{V}_{AB} = \vec{V}_A - \vec{V}_B$ and $V_{AB} = \sqrt{V_A^2 + V_B^2 - 2V_AV_B\cos 180^0} = V_A + V_B$

Similarly, the apparent velocity of B relative to that of A is

$\vec{V}_{BA} = \vec{V}_B - \vec{V}_A$ and $V_{BA} = \sqrt{V_B^2 + V_A^2 - 2V_BV_A\cos 180^0} = V_B + V_A$

Case –iii) suppose the two objects A and B are moving with the velocities V_A and V_B making an angle 90^0 at time 't' shown in the figure



The apparent velocity of 'A' relative to that of 'B' is,

$\vec{V}_{AB} = \vec{V}_A - \vec{V}_B$ and $V_{AB} = \sqrt{V_A^2 + V_B^2 - 2V_AV_B\cos 90^0} = \sqrt{V_A^2 + V_B^2}$

8. Define unit vector, null vector and position vector.

A. **Unit vector: -** A vector whose magnitude is unity(1) is called unit vector. It is represented by 'A'

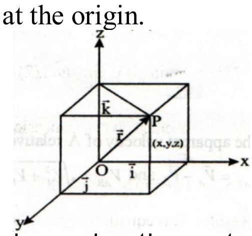
Unit vector along the direction of $\vec{A}$ is given by $\hat{A} = \frac{\vec{A}}{|\vec{A}|}$

It has no units and dimensions.

Ex: in a coordinate $\hat{i}, \hat{j}, \hat{k}$ system are the unit vector along X,Y&Z axis respectively. (or) $|\hat{i}| = |\hat{j}| = |\hat{k}| = 1$

Null vector: - A vector whose magnitude is zero(0) is called a null vector. It is represented by 'O'

Ex: The position of the particle at the origin.



Position vector: - A vector which specifies the position of an object with respective to the origin of a coordinate system is called as position vector of the object in the system.

Ex: If P(X,Y,Z) are the coordinates of the object P and 'O' is the origin of the system then position vector is given by $\vec{OP} = x\hat{i} + y\hat{j} + z\hat{k}$, $|\vec{OP}| = \sqrt{x^2 + y^2 + z^2}$

1. Explain the advantages and disadvantages of friction.

A. Advantages

1. We cannot walk without friction between feet and ground.
2. 'Brakes' are able to stop the vehicles only due to friction between brake shoes and the inner surface of the brake drum.
3. We are able to pick up a Book due to friction between Hand and the Book.
4. Nails and screws are fitted in the walls due to friction.

Disadvantages

1. Heat generated due to friction, decreases the efficiency of engine.
2. Friction results in the large amount of power loss in engines.

2. Mention the methods used to decrease friction.

A. **Polishing:** By polishing the surfaces, frictional force can be reduced.

Lubricants: Lubricants like oil, grease which forms a thin layer between two surfaces in contact and it reduces the friction.

Ball – Bearings: The wheels of motor vehicles, cycles and dynamos are provided with ball bearings to reduce friction.

Streamlining: By making front portion of aero planes and vehicles to reduce friction due to air.

3. Explain the terms limiting friction, dynamic friction and rolling friction.

A. **Limiting friction(f_S):** It is the maximum value of static friction between two surfaces in contact when a body is just ready to slide over a surface is called limiting friction.

Kinetic/Sliding friction (f_K): The resistance force encountered by a sliding body on surface is called kinetic/sliding friction.

Rolling friction(f_R): The resistance force encountered by a rolling body on the surface is called rolling friction.

4. Why are shock absorbers used in motor cycles and cars? Explain.

A. When the vehicle moves over an uneven road, it receives a jerk. So the vehicle receives the impulsive force. To minimize this impact shock absorbers are used.

$$\text{Impulse} = F(\Delta t) \Rightarrow F\alpha\left(\frac{\text{Impulse}}{\Delta t}\right)$$

The shock absorbers increase the time of the jerk, thereby reduce the impulsive force. This minimizes the damage to the vehicles.

5. State the laws of rolling friction.

A. The laws of rolling friction can be stated as follows.

1. Rolling friction is directly proportional to normal reaction.
2. Rolling friction depends upon area of contact.
3. Rolling friction depends upon radius of rolling body.
4. Rolling friction decrease with increase of hardness of the surface.

6. Define the terms momentum and impulse. State and explain the law of conservation of linear momentum. Give its examples.

A. **Momentum (P):** The product of mass and velocity of a body is called momentum.

Momentum = (Mass)(Velocity)

Impulse (J): Change in momentum of a body during small interval of time is called impulse.

$$\text{Impulse}(J) = (\text{Force})(\text{time interval})$$

$$J = (ma)(t) \Rightarrow m\left(\frac{v-u}{\cancel{t}}\right)(\cancel{t})$$

$$\boxed{J = (mv - mu)}$$

Law of conservation of linear momentum: It is states that "the total momentum of an isolated system remains constant if there is no net external force acting on it"

Explanation: Consider two smooth, non-rotating spheres of masses m_1 and m_2. Let u_1 and u_2 be their initial velocities. Let v_1 and v_2 be their final velocities after head on collision. According to law of conservation of linear momentum.

Momentum of the system before collision = Momentum of the system after collision.

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2.$$

Examples: 1. Motion of a Rocket.
2. Bullet-Gun motion.

7. Why pulling the lawn roller is preferred than pushing the lawn roller?

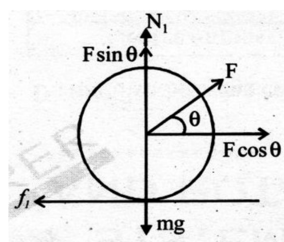
A. **Pulling:** Roller of mass 'm' is kept on a rough horizontal surface. The weight 'mg' is acting vertically downwards. The normal reaction 'N' acts upwards. Let 'F' be the pulling force acting on the roller towards right. The horizontal component '$F\cos\theta$' moves the body. The vertical component '$F\sin\theta$' acts upwards.

Total upward force = Total down ward force.

$$N_1 + F\sin\theta = mg$$

$$N_1 = mg - F\sin\theta$$

$$f_1 = \mu_R N_1 = \mu_R(mg - F\sin\theta)$$



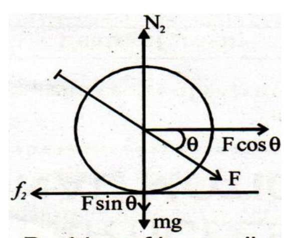
Pulling of lawn roller

Pushing: Roller of mass 'm' is kept on a rough horizontal surface. The weight 'mg' is acting vertically downwards. The normal reaction 'N' acts upwards. Let 'F' be the pushing force acting on the roller towards left. The horizontal component '$F\cos\theta$' moves the body. The vertical component '$F\sin\theta$' acts downwards.

Total upward force = Total down ward force.

$$N_2 = mg + F\sin\theta$$

$$f_2 = \mu_R N_2 = \mu_R(mg + F\sin\theta)$$



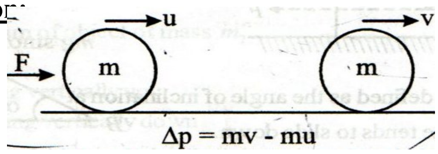
Pushing of lawn roller

As $f_1 < f_2$, less force is required to pull the lawn roller. Pulling is preferred to pushing.

1. State Newton's second law of motion. Hence derive the equation of motion F = ma from it. A body is moving along a circular path such that its speed always remains constant. Should there be a force acting on the body?

A) **<u>Newton's Second law of motion</u>:** The rate of change of momentum of a body is directly proportional to the net external force acting on the body and it takes place in the direction of the force that acts

<u>Derivation</u>:



Consider a body of mass 'm' moving with a velocity 'v'. under the action of an external force 'F' in the direction of velocity.

$\boxed{P = mv - - - - - (1)}$ Where 'P' is momentum of the body

According to Newton's **II** law of motion

$$F \alpha \frac{dp}{dt} \quad (\therefore P = mv)$$

$$\boxed{F = k\frac{dp}{dt} - - - - - - (2)}$$

From equation (1) and (2)

$$F = k\frac{d(mv)}{dt}$$

$$F = k\,m\left(\frac{dv}{dt}\right)$$

$$F = k\,ma \qquad \left(\therefore \frac{dv}{dt} = a\right)$$

If F = 1N, m = 1kg, and a = 1m/s^2, Then k = 1

$$\boxed{F = ma}$$

i) Yes, centripetal force must action on the body. Direction of velocity of the body changes point to point in circular path.

2. The linear momentum of a particle as a function of time t is given by p = a + BT, where a and b are positive constants, what is the force acting on the particle?

A) Given, Linear momentum p = a + bt, where a & b are constants

Newton's 2nd law, $F = \frac{dp}{dt}$, $F = \frac{d}{dt}[a + bt]$

$F = 0 + b.\frac{dt}{dt} \qquad F = b$.

3. Calculate the time needed for a net force of 5N to change the velocity of a 10kg mass by 2m/s.

A) Given, Force F_{net} = 5N, mass m = 10kg

Change in velocity(Δ v) = 2m/s, time t = ?

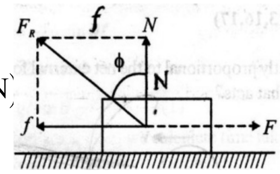
$$F = ma = m\left(\frac{Change\ in\ velocity}{time}\right) = \frac{m(\Delta v)}{t}$$

$$5 = \frac{10(2)}{t} \qquad \therefore t = 4s$$

4. Define angle of friction and angle of repose. Show that angle of friction is equal to angle of repose for a rough inclined plane.

A) **<u>Angle of friction</u>** (ϕ) **:** The angle between normal reaction and resultant of normal reaction and frictional force is called angle of friction.

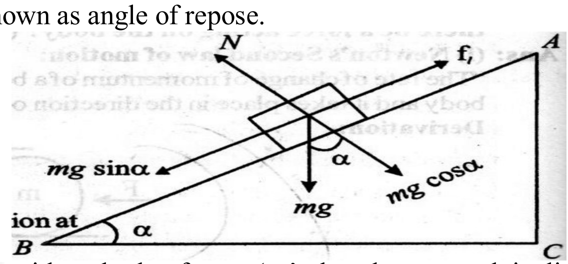
From the figure, we have



$$Tan(\phi) = \frac{f}{N} = \frac{\mu_s N}{N} \quad (\therefore f = \mu_s N)$$

$$\boxed{\mu_s = Tan(\phi) - - - - - - (1)}$$

<u>Angle of repose</u> (α): It is defined as the angle of inclination at which the body tends to slides down is known as angle of repose.



Consider a body of mass 'm' placed on a rough inclined plane which makes an angle ' α' with horizontal as shown in figure.

The force acting on the body are.

1. Weight 'mg' acting vertically downwards
2. Normal reaction 'N' acting perpendicular to the inclined plane.
3. Limiting frictional force 'f_L' acting upwards along the inclined plane.

The weight of the body 'mg' is resolved into two components.

1. $mg\cos\alpha$ Perpendicular to the inclined plane.
2. $mg\sin\alpha$ Acting downwards along the inclined plane.

At angle of repose, the body is in equilibrium. So, the net force acting on it is zero.

$$mg\sin\alpha - f_L = 0$$

$$f_L = mg\sin\alpha - - - - - - - - (2)$$

$$N = mg\cos\alpha - - - - - - - - (3)$$

And Limiting friction

$$f_L = \mu_s N - - - - - - (4)$$

From (2),(3) and (4) $mg\sin\alpha = mg\cos\alpha$

$$\mu_s = \frac{\cancel{mg}\sin\alpha}{\cancel{mg}\cos\alpha} \qquad \boxed{\mu_s = Tan\alpha - - - - - (5)}$$

From equation (1) and (5), it is clear that angle of friction is equal to angle of repose (α)

A block of mass 4kg is resting on a rough horizontal force of 30N is applied on it. If g = 10m/s^2, find the total contact force exerted by the plane on the block.

M = 4kg, and g = 10m/s^2, N = mg = 4 x 10 = 40 N,

Applied force (*f*) = 30N

$$F_R = \sqrt{f^2 + N^2}\,;\ F_R = \sqrt{(30)^2 + (40)^2}$$

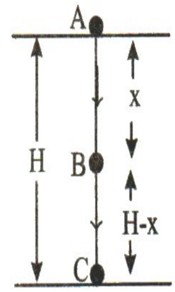
$$F_R = \sqrt{900 + 1600} = \sqrt{2500}$$

$$F_R = 50N$$

1. State the law of conservation of energy and verify it in case of a freely falling body. What are the conditions under which the law of conservation of energy is applicable?

A) **Statement:** "The total mechanical energy of a system is constant, if the internal forces doing work on it are conservative and the external forces do no work"

At Point A: Height of the ball =H, velocity of the ball = v_A=0, distance travelled by the ball =0



K.E $K=\frac{1}{2}mv_A^2=\frac{1}{2}m(0)^2=0$

P.E = mgH

$T.E_A$ = P.E+K.E

$T.E_A$ = 0+mgH

$$\boxed{T.E = mgH..............(1)}$$

At Point B: Height of the ball = H-x, velocity of the ball =v_B, distance travelled by the ball =x

From $v_B^2-v_A^2=2as; v_B^2-0^2=2gx$

$$\Rightarrow v_B^2=2gx$$

$$K=\frac{1}{2}mv_B^2=\frac{1}{\cancel{2}}m\left[\cancel{2}gx\right]=mgx$$

P.E= mg(H-x)=mgH-mgx

T.E = P.E+K.E

T.E = mgH- ~~mgx~~ + ~~mgx~~

$$\boxed{T.E = mgH..............(2)}$$

At Point C: Height of the ball =0 , velocity of the ball= v_e, distance travelled by the ball =H

From $v_c^2-v_A^2=2as$

$$v_c^2-0=2gH\Rightarrow v_c^2=2gH$$

$$K=\frac{1}{2}mv_c^2=\frac{1}{\cancel{2}}m\left(\cancel{2}gH\right)=mgH$$

P.E $U=mgh=0\left(\because h=0\right)$

T.E = P.E+K.E

$$E_c=mgH+0$$

$$\boxed{T.E = mgH..............(3)}$$

Conditions:

1) The total mechanical energy of the system remains constant, under the action of the conservative forces

2) The total mechanical energy of the system not, constant, under the action of non conservative forces

b) A machine gun fires 360 bullets per minute and each bullet travels with a velocity of 600m/s. If the mass of each bullet is 5gm. Find the power of the machine gun?

A) Let velocity of each bullet v = 6000m/s

Mass of each bullet m = 5gm = 5×10^{-3}kg.

No. of bullets fired n = 360, Time t = 1minute = 60sec,

Power P =?

$$\text{Power}(P)=\frac{1}{2}\frac{mnv^2}{t}=\frac{1}{2}\frac{0.005\times360\times600\times\cancel{600}}{\cancel{60}}$$

$$\text{Power}(P)=\frac{1}{\cancel{2}}\times\frac{5}{1\cancel{000}}\times\cancel{108}\times10\cancel{000}$$

$$\text{Power}(P)=5\times1080=5400=5.4kw$$

2. What are collisions? Explain the possible types of collisions? Develop the theory of one Dimensional elastic collision?

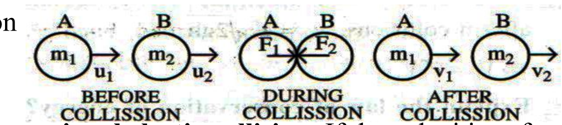
A) **Collision:** The strong interaction among bodies involving exchange of momenta in small interval of time, is called a collision

Ex: Collision 2-billiard balls

Collisions are of two types:

Elastic collision: The collision in which both momentum and kinetic energy is constant is called elastic collision

Inelastic collision: The collision in which momentum remains constant but not kinetic energy is called inelastic collision



One dimensional elastic collision: If the velocities of the objects involved in collision are along the same straight line before and after collisions are known as one dimensional collision.

Consider two smooth spheres moving along the straight line joining their centers of Mass with initial velocities u_1 and u_2. They undergo head on collision and move along the same line after collision with final velocities v_1 and v_2

Applying law of conservation of linear momentum

$M_1u_1+m_2u_2=m_1v_1+m_2v_2$

$M_1(u_1-v_1)=m_2(v_2-u_2)$…………..(1)

Applying law of conservation of kinetic energy

$$\frac{1}{2}m_1u_1^2+\frac{1}{2}m_2u_2^2=\frac{1}{2}m_1v_1^2+\frac{1}{2}m_2v_2^2$$

$$\frac{1}{2}m_1\left(u_1^2-v_1^2\right)=\frac{1}{2}m_2\left(v_2^2-u_2^2\right)........(2)$$

$$\frac{(2)}{(1)}\Rightarrow\frac{m_1\left(u_1+v_1\right)\cancel{\left(u_1-v_1\right)}}{m_1\cancel{\left(u_1-v_1\right)}}=\frac{m_2\left(v_2+u_2\right)\cancel{\left(v_2-u_2\right)}}{m_2\cancel{\left(v_2-u_2\right)}}$$

$$u_1+v_1=v_2+u_2$$

$$\boxed{\Rightarrow\ (u_1-u_2)=(v_2-v_1)..........(3)}$$

The relative velocity of approaching before collision is equal to relative velocity of separation after collision

From eq (3), $v_2=u_1+v_1-u_2$ sub, in eq (1)

$$m_1\left(u_1-v_1\right)=m_2\left(u_1+v_1-u_2-u_2\right)$$

$$m_1u_1-m_1v_1=m_2u_1+m_2v_1-2m_2u_2$$

$$\boxed{v_1=\left(\frac{m_1-m_2}{m_1+m_2}\right)u_1+\left(\frac{2m_2}{m_1+m_2}\right)u_2}$$

$$from\,eq\,(3): v_1=v_2-u_1+u_2\ \ sub.it\ in\ eq\,(1)$$

$$m_1\left(u_1-v_2+u_1-u_2\right)=m_2\left(v_2-u_2\right)$$

$$m_1u_1-m_2v_2+m_1u_1-m_1u_2=m_2v_2-m_2u_2$$

$$2m_1u_1+m_2u_2-m_1u_2=m_1v_2+m_2v_2$$

$$\boxed{v_2=\left(\frac{m_2-m_1}{m_1+m_2}\right)u_2+\left(\frac{2m_1}{m_1+m_2}\right)u_1}$$

3. Develop the notions of work and kinetic energy and show that it leads to work energy theorem

A) **Work:** Work is said to be done, when a force acting on a body moves it, through some distance in the direction of the force **W= F.s cosθ**

Ex: A stretched rubber card.

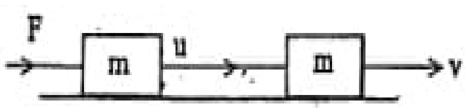
Kinetic energy: It is the energy possessed by a body by virtue of its motion is called kinetic energy

$$KE = \frac{1}{2}mv^2$$

Ex: i) A vehicle in motion. ii) water in a river

Work energy theorem: The work done by a net force acting on a body is equal to change in its kinetic energy.

$$W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$



Proof: - Consider a particle of mass 'm' is moving with initial velocity 'u' of final velocity V. Let 'a' be its acceleration and s be its distance travelled. The kinetic relation is given by

$V^2-u^2 = 2as$……………..(1)

Multiplying both sides by $\frac{m}{2}$, we have

$$\frac{m}{2}\left[v^2-u^2\right] = \frac{m}{2}[2as] \Rightarrow \frac{1}{2}mv^2 - \frac{1}{2}mu^2 = mas$$

$$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = mas = FS........(2)$$

$$\boxed{\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = W}$$

W = (Final K.E) – (Initial K.E)

Thus, Work Energy theorem is proved.

4. What is potential energy? Derive an expression for the gravitational potential energy.

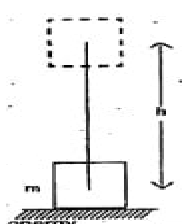
A) **Potential energy:-** The energy possessed by a body by virtue of its position or state is called potential energy

1) Energy possessed by water stored in a dam

2) A stretched rubber card

Formula for P.E: - The potential energy is measured by the work done in lifting a body through a height 'h' against gravitational force.

(Mass lifted to a height)



Consider a body of mass m on the body against gravitational force.

Force F= weight of the body

F=mg Height lifted =h

W= gravitational force x height lifted

W= mgh

This work done is stored as potential energy

Potential energy P.E = mgh

3. Find the useful power used in pumping 3425 m^3 of water per hour from a well 8 m deep to the surface, supposing 40% of the horse power during pumping is wasted. What is the horse power of the engine?

A) Volume of the water to be pumped is V = 3425 m^3

Density of water, d = 1000 kg/m^3

Mass of the water that has to be pumped is M = (volume)density = (3425)10^3 kg

G = 10 m/s^2, height, h = 8m, time = 1 hour = 3600 seconds, 1 hp = 746 w

$$\text{Useful power } P_{useful} = \frac{60}{100}P_{total} \Rightarrow P_{total} = \frac{100}{60}\frac{Mgh}{t}$$

$$P_{Total} = \frac{100}{6}\left(\frac{3425\times10^3\times10\times8}{3600}\right) = (126)10^3\ w = \frac{126\times10^3}{746}H.P = 168H.P$$

3. A pump is required to lift 600 kg of water per minute from a well 25 m deep and to eject it with a speed of 50 ms^{-1}. Calculate the power required to perform the above task?

A) Mass of water that has to be lifted is M = 600 kg

Height to be lifted, h = 25 m

g = 10 m/s^2, velocity of ejection v = 50ms^{-1}, time = 60 seconds

Power,

$$P = \frac{Mgh + \frac{1}{2}Mv^2}{t} = \frac{600\times10\times25+\frac{1}{2}\times600\times50\times50}{60} = 15000W = 15KW$$

4. From a height of 20 m above a horizontal floor, a ball is thrown down with initial velocity 20 m/s. After striking the floor, the ball bounces to the same height from which it was thrown. The coefficient of restitution for the collision between the ball and the floor is (g = 10 m/s^2)

A) e = velocity of bouncing/velocity of striking

The striking velocity is obtained with $u_1^2 - u^2 = 2as$

Here u = 20 m/s, a = g = 10 m/s^2, s = h = 20m

$U_1^2 - 20^2 = 2\times10\times20$ $U_1 = 20\sqrt{2}m/s$

As it rises to 20 m, the bouncing velocity

Given by $v_1 = -\sqrt{2gh} = -20m/s$

E = velocity of bouncing/velocity

of striking $\Rightarrow e = \frac{v_2 - v_1}{u_1 - u_2} = -\frac{v_1}{u_1} = \frac{20}{20\sqrt{2}} \Rightarrow e = \frac{1}{\sqrt{2}}$

5. A ball falls from a height of 10 m on to a hard horizontal floor and repeatedly bounces. If the coefficient of restitution is $\frac{1}{\sqrt{2}}$, what is the total distance travelled by the ball before it ceases to rebound?

A) Given h = 10m, coefficient of restitution e = $\frac{1}{\sqrt{2}}$

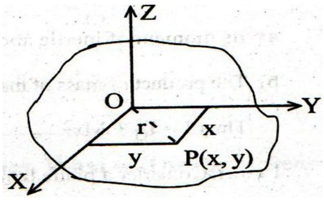
Total distance travelled before it ceases to rebound is

$$d = h\left(\frac{1+e^2}{1-e^2}\right) \Rightarrow d = 10\left(\frac{1+\left[\frac{1}{\sqrt{2}}\right]^2}{1-\left[\frac{1}{\sqrt{2}}\right]^2}\right) = 30\ m$$

1. (a) State and prove perpendicular axes theorem.

A. **Statement:-** The moment of inertia of a plane lamina about an axis passing through a point perpendicular to its plane is equal to the sum of the moments of inertia about two mutually perpendicular axes in its plane passing through the same point.

$\boxed{I_Z = I_x + I_y}$



Proof: Consider a plane lamina of mass 'M' It is divided into number of small particles, each of mass 'm'

Let a particle P of mass 'm' with coordinates (x,y) be at a distance 'r' from the axis OZ.

Moment of inertia about Y - axis is $I_y = \sum Mx^2$

Moment of inertia about X - axis is $I_x = \sum My^2$

Moment of inertia about Z - axis is $I_z = \sum M(OP)^2$

From diagram, $OP^2 = x^2+y^2$

Multiplying on both sides by $\sum M$

$\sum M(OP)^2 = \sum M(x^2+y^2)$

$\sum M(OP)^2 = \sum M(x)^2 + \sum M(y)^2$

$\boxed{I_Z = I_x + I_y}$

Hence the theorem is proved.

(b) If a thin circular ring and a thin flat circular disc of same mass have same moment of inertia about their respective diameters as axes find the ratio of their radii.

MI of a circular **ring** about the diameter $I_1 = \frac{MR_1^2}{2}$

MI of a circular **disc** about the diameter $I_2 = \frac{MR_2^2}{4}$

Given $I_1 = I_2$, $\frac{MR_1^2}{2} = \frac{MR_2^2}{4}$, $\frac{R_1}{R_2} = \frac{1}{\sqrt{2}} \Rightarrow R_1:R_2 = 1:\sqrt{2}$

2. State and prove the principal of conservation of angular momentum. Explain the principle of conservation of angular momentum with examples.

Statement:- When there is no external torque on a rotating system, the angular momentum of the system remains constant. $\tau = \frac{dL}{dt}$

when $\tau = 0$, then $\frac{dL}{dt} = 0$, $L = 0, I\omega = \text{constant}$

Derivation: - From Newton's II law of motion.

Example 1: A person stands on turn table with equal weights in his stretched hands. When the person brings his hands closer to his body then his angular velocity increase due to decrease of moment of inertia.

Angular momentum when hands stretched $L_1 = I_1\omega_1$

Angular momentum when hands closed $L_2 = I_2\omega_2$

$L_1 = L_2$

$I_1\omega_1 = I_2\omega_2$

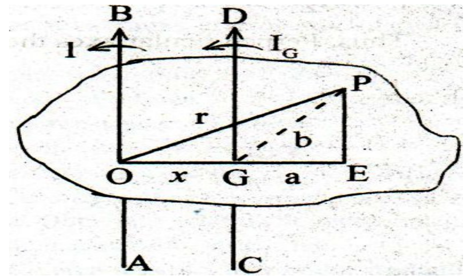
But $I_2 < I_1$ then $\omega_2 > \omega_1$

Example 2: A diver leaves the spring board with some angular velocity and jumps upwards. He brings his hands and legs close to his body. His moment of inertia decreases. His angular velocity increases due to LCAM. This help to make more number of somersaults quickly

3. (a) State and prove parallel axes theorem.

A) **Statement:** The moment of inertia of a rigid body about any axis is equal to sum of moment of inertia about a parallel axis through its centre of mass and product of the mass of the body and the square of the perpendicular distance between the two parallel axes.

$\boxed{I = I_G + Mr^2}$



Proof:- Consider a plane lamina of mass 'M' having its centre of mass at 'G'. Consider an axis AB passing through the point 'O' about which the moment of inertia of the body is to be found. Consider a particle of mass 'm' at a distance r from the axis AB. Consider another axis CD Passing through G and parallel to AB, so that the distance between the two parallel axis 'x'

MI of a body about the axis AB is $I = \sum mr^2 \ldots\ldots(1)$

MI of a body about the centre $I_G = \sum mr^2 \ldots\ldots(2)$

From $\Delta OPE.\ OP^2 = (OE)^2 + EP^2$

$OP^2 = (OG+GE)^2 + EP^2$

$OP^2 = OG^2 + GE^2 + 2(OG)(GE) + EP^2$

$(\text{From } \Delta GPE,\ GE^2 + EP^2 = GP^2)$

$OP^2 = OG^2 + GP^2 + 2(OG)(GE)$

$\Rightarrow r^2 = x^2 + b^2 + 2xa$

Now applying $\sum m$ on both sides

$\sum mr^2 = \sum m(x^2+b^2+2xa)$

$I = \sum mx^2 + \sum mb^2 + \sum m(2xa)$

$I = Mx^2 + I_G + \sum m(2xa)$

But, algebraic sum of the moments about centre of mass $\sum mxa = 0$

$\boxed{I = I_G + Mr^2}$

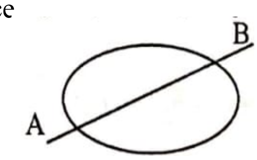
(b) For a thin flat circular disc, the radius of gyration about a diameter as axis is k. If the disc is cut along a diameter AB as shown into two equal pieces, then find the radius of gyration of each piece about AB.

moment of inertia changes, but radius of gyration remains same. Radius of gyration $K = \sqrt{\frac{I}{M}}$,

when the disc cut into two equal parts $M^| = \frac{M}{2}$, $I^| = \frac{I}{2}$

the radius of gyration of each piece

$K^| = \sqrt{\frac{I^|}{M^|}} = \sqrt{\frac{\frac{I}{2}}{\frac{M}{2}}} = \sqrt{\frac{I}{M}} = K$



1. Define vector product. Explain the properties of a vector product with two examples

A) **Vector Product: -** Cross product of two vectors is equal to product of magnitudes of the vectors and sine of angle between the vectors.

$$\boxed{\vec{A}\times\vec{B} = |\vec{A}||\vec{B}|\sin\theta}$$

Properties:-

1) Cross product does not obey commutative law

$$\vec{A}\times\vec{B} \neq \vec{B}\times\vec{A} \Rightarrow (\vec{A}\times\vec{B}) = -(\vec{B}\times\vec{A})$$

2) It obeys distributive law

$$\vec{A}\times(\vec{B}+\vec{C}) = \vec{A}\times\vec{B}+\vec{A}\times\vec{C}$$

3) The magnitude cross product of two vectors which are parallel is zero

$$\theta=0; |\vec{A}\times\vec{B}| = AB\sin 0^0 = 0$$

4) For perpendicular vectors,

$$\theta = 90^0, |\vec{A}\times\vec{B}| = AB\sin 90^0 = AB$$

Example:-

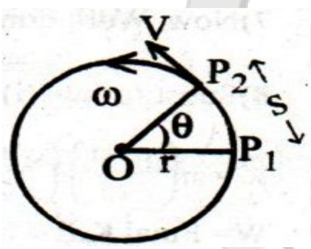
1) Torque $\vec{T}=\vec{r}\times\vec{F}$ 2) Angular momentum $\vec{L}=\vec{r}\times\vec{p}$

2. Define angular velocity (ω). Derive $v=r\omega$.

A) **Angular velocity (ω):-** The rate of change of angular displacement of a body is called angular velocity

$$\boxed{\text{Angular velocity}(\omega) = \frac{d\theta}{dt}}$$

Derivation: - Let a particle be moving along circular path.



Let r = radius of the circular path

s = distance travelled by the particle from P_1 to P_2

v = Linear velocity of the particle

ω = Angular velocity ofthe particle

The arc P_1P_2 of length 's' subtends angle at centre,

From the property, length of arc= radius x angle

$S = r.\theta$

Differentiating $S = r.\theta$ with respect to 'time'

$$\frac{ds}{dt} = \frac{d}{dt}(r\theta) \quad \frac{ds}{dt} = r\frac{d\theta}{dt} \quad (\therefore r \text{ is constant})$$

$$\boxed{v = r\omega} \quad \left(\therefore \frac{ds}{dt} = v \text{ and } \frac{d\theta}{dt} = \omega\right)$$

3. Explain about the entre of mass of earth-moon system and its rotation around the sun.

A) The Earth-Moon system rotates about the common centre of mass. The mass of the Earth is about 81times that of the Moon. This reveals that the centre of mass of the Earth-Moon system is relatively nearer to the centre of the Earth.

The interaction of the earth and moon does not affect the motion of the centre of mass of the earth-moon system. The gravitational attraction of the sun is the only external force that acts on the earth-moon system and it moves in an elliptical path around the sun.

4. Distinguish between centre of mass and centre of gravity.

Centre of mass	Centre of gravity
The point, where total mass of the body is concentrated is called centre of mass.	The point, where total weight of the body always acts is called centre of gravity.
In the case of small and regular bodies centre of mass and centre of gravity coincide	In the case of very large bodies centre of mass and centre of gravity do not coincide
It does not depend on'g'.	It depends on 'g'
Centre of mass lie within the body (or) outside the body.	Centre of gravity lie within the body only

5. Define angular acceleration and torque establishes the relation between angular acceleration and torque

A) **Angular acceleration:-** The rate of change of angular velocity is called angular acceleration.

$$\boxed{\alpha = \frac{d\omega}{dt}}$$

Torque:- The rate of change of angular momentum is called torque.

$$\boxed{\tau = \frac{dL}{dt}}$$

Relation between angular acceleration and torque:

Consider a rigid v of mass 'M' rotating in a circular path of radius 'R' with angular about fixed axis.

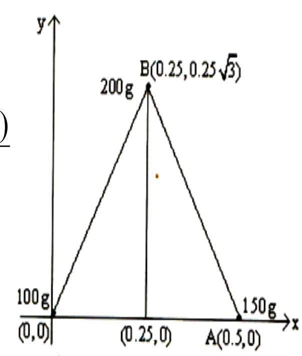
By definition, $\tau = \frac{dL}{dt} = \frac{d(I\omega)}{dt}$

$$\tau = I\frac{d\omega}{dt}, \quad \text{But } \frac{d\omega}{dt} = \alpha, \quad [\text{I= constant}]$$

$$\boxed{\tau = I\alpha}$$

6. Find the centre of mass of three particles at the vertices of an equilateral triangle. The masses of the particles are 100g, 150g and 200g respectively. Each side of the equilateral triangle is 0.5m long.

A) The coordinates of points O, A and B forming the equilateral triangle are respectively (0,0),(0.5,0),(0.25,0.25$\sqrt{3}$). Let the masses 100g, 150g and 200g be located at O, A and B be respectively. Then



$$X = \frac{m_1x_1+m_2x_2+m_3x_3}{m_1+m_2+m_3}$$

$$X = \frac{(100(0)+150(0.5)+200(0.25))}{(100+150+200)}$$

$$X = \frac{0+75+50}{450} = \frac{\cancel{125}}{\cancel{450}} = \frac{5}{18}m$$

$$Y = \frac{m_1y_1+m_2y_2+m_3y_3}{m_1+m_2+m_3}$$

$$Y = \frac{(100(0)+150(0)+200(0.25\sqrt{3}))}{100+150+200}$$

$$Y = \frac{\cancel{50}\sqrt{3}}{\cancel{450}} = \frac{\sqrt{3}}{9}m = \frac{1}{3\sqrt{3}}m$$

3. Derive the equation for the kinetic energy and potential energy of a simple harmonic oscillator and show that the total energy of a particle in simple harmonic motion is constant at any point on its path.

Kinetic energy:

A) Displacement of SHM is given by $y = A\sin\omega t$

Velocity $v = \dfrac{dy}{dt} = \dfrac{d}{dt}(A\sin\omega t)$

$= A.\omega\cos\omega t = A\omega\sqrt{1-\sin^2\omega t}$

Velocity $v = \omega\sqrt{A^2 - y^2}$

The K.E of the particle is given by

$$\boxed{KE = \frac{1}{2}mv^2 = \frac{1}{2}m\omega^2\left(A^2 - y^2\right)}$$

Potential energy:- Potential energy of a simple harmonic oscillator is equal to the work done giants the restoring force in producing the displacement 'y'

When displacement =0, F=0

When displacement=y, fore=F

Average force $= \dfrac{0+F}{2} = \dfrac{F}{2}$

Work done= Average force x displacement

$$\therefore W = \frac{F}{2}y$$

If 'm' is the mass of the particle and 'a' is the acceleration, then

$$W = \frac{(ma)y}{2}. \quad [\because F = ma]$$

The work done on the particle $W = \dfrac{m\omega^2 y^2}{2}. \quad [\because a = \omega^2 y]$

This work done is stored as potential energy

$$\boxed{\therefore PE = \frac{1}{2}m\omega^2 y^2}$$

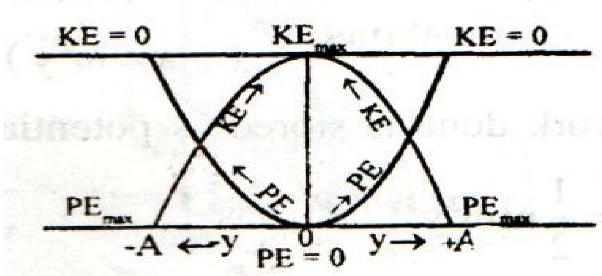
Total energy TE=PE+KE:

$$E = \frac{1}{2}m\omega^2 y^2 + \frac{1}{2}m\omega^2\left(A^2 - y^2\right)$$

$$\boxed{E = \frac{1}{2}m\omega^2 A^2}$$

Total energy is same at all points. Hence law of conservation of energy is proved in the case of particle undergoing S.H.M

Note: Variation of P.E and K.E with displacement is shown below

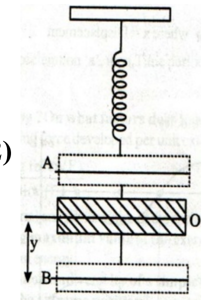


4. Obtain an equation for the frequency of oscillation of spring of force constant k to which g mass m is attached:

A) Consider a block of mass 'm' suspended from one end of a spring. The spring is suspended from a fixed point as shown in the figure

Let the block be pulled down and released

At any instant, 'y' be the displacement of the block, from the mean position. The restoring force (F) acting on the body is divide by proportional to the displacement (y) in opposite direction



Restoring force of spring $F\alpha - y$

$\therefore F = -ky$ .... **(1)**

K is a constant called spring constant

Newton's second law F= ma......... (2)

From (1) and (2)

ma= -ky

$a = \dfrac{-k}{m}y$.............(3)

Comparing equation (3) with standard equation of SHM

$a = -\omega^2 y \qquad \dfrac{-k}{m}\cancel{y} = -\omega^2\cancel{y}$

$Then\ \omega^2 = \dfrac{k}{m} \Rightarrow \omega = \sqrt{\dfrac{k}{m}}$

$But\ T = \dfrac{2\pi}{\omega} = \dfrac{2\pi}{\sqrt{\dfrac{k}{m}}} = 2\pi\sqrt{\dfrac{m}{k}}$

$\therefore$ Time period of loaded spring

$$\boxed{T = 2\pi\sqrt{\frac{m}{k}}}$$

Frequency of oscillation of loaded spring is

$n = \dfrac{1}{T} \qquad \therefore n = \dfrac{1}{2\pi\sqrt{\dfrac{m}{k}}}$

$$\boxed{\therefore n = \frac{1}{2\pi}\sqrt{\frac{k}{m}}}$$

5. Define simple harmonic motion? Give two examples.

A) **Definition of SHM:** A body is said to be in simple harmonic motion provided.

(i) The motion should be to and fro and is periodic about a fixed point

(ii) The acceleration should always be directed towards the mean position and always directly proportional to the displacement from the mean position

(iii) Acceleration and displacement are always in opposite direction

Ex(1): Oscillations of a loaded spring suspended from a rigid support.
k = Spring constant

Ex(2): Oscillations of a simple pendulum with small amplitude and vibrations of strings in musical instruments.

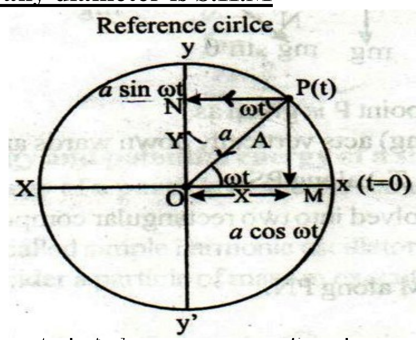
Ex(3): The projection of a particle performing uniform circular motion on any diameter.

Ex(4): Oscillation of a liquid column in a U tube.

1. Define simple harmonic motion. Show that the motion of (point) projection of a particle performing uniform circular motion, on any diameter is simple harmonic

A) **Definition of SHM: -**A body is said to be in simple harmonic motion, if it moves to and fro along a straight line, about its mean position such that, at any point its acceleration is proportional to its displacement but opposite in direction and directed always towards the mean position

To show that the projection of uniform circular motion on any diameter is S.H.M



Consider a particle 'p' is moving uniformly on a circle of radius 'A' with angular speed 'ω' in anti clock wise direction

Displacement: The distance of the particle executing SHM measured along the path form the men position gives the displacement. At t=0 the particle is at X. After the time 't' the particle is at 'P' . The angular displacement of the particle during this time is $\theta = \omega L$

From triangle ONP

$$Sin\theta = \frac{ON}{OP} = \frac{y}{A} \qquad \boxed{\therefore y = A\sin\omega t}$$

Velocity (v): The rate of change of displacement is called velocity

$$v = \frac{dy}{dt} = \frac{d}{dt}(A\sin\omega t)$$

$$\therefore v = A\omega\cos\omega t$$

$$\therefore v = A\omega\sqrt{1-\sin^2\omega t}$$

$$\left(\because \cos\omega t = \sqrt{1-\sin^2\omega t}\right)$$

$$\boxed{\therefore v = \omega\sqrt{A^2 - y^2}} \qquad \left(\because \sin\omega t = \frac{y}{A}\right)$$

Y=0, velocity is maximum $V_{max} = A\omega$

Acceleration (a): The rate of change of velocity is called acceleration

$$a = \frac{dv}{dt} = \frac{d}{dt}(A\omega\cos\omega t) \qquad [\because v = A\omega\cos\omega t]$$

$$a = -A\omega(\omega\sin\omega t)$$

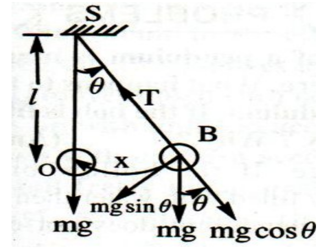
$$a = -A\omega^2\sin\omega t \qquad [\because y = A\sin\omega t]$$

$$a = -\omega^2 y$$

(y=A) acceleration is maximum $a_{max} = -\omega^2 A$

2. Show that the motion of simple pendulum is simple harmonic and hence drive an equation for its time period. What is seconds' pendulum?

A) The distance between the point of suspension and the centre of gravity of the sphere is known as the length of the pendulum



At any instant, let the bob is making as angle θ with the vertical. The weight (mg) can be resolved into two perpendicular components. One component ms cos θ balance the tension and the other component mgsin θ provides restoring force

Restoring force $F = mg\sin\theta$...........(1)

But From Newton's II Law $F = ma$.........(2)

From (1) & (2) $\cancel{m}a = \cancel{m}g\sin\theta$

$\Rightarrow a = g\sin\theta$

$\Rightarrow a = g\theta$ (when 'θ' is very small, $\sin\theta \simeq \theta$)

Also $x = l\theta$ (arc length = radius × angle)

$$\theta = \frac{x}{l} \qquad a = -g\left(\frac{x}{l}\right) \Rightarrow a = -\left(\frac{g}{l}\right)x.........(3)$$

Hence, the motion is simple harmonic motion if ω is angular velocity of the bob then its acceleration

$a = -\omega^2 x$...........(4)

Substitute above value in equation (3)

$$\cancel{-}\omega^2 \cancel{x} = \cancel{-}\left(\frac{g}{l}\right)\cancel{x} \Rightarrow \omega^2 = \left(\frac{g}{l}\right)$$

$$\omega = \sqrt{\frac{g}{l}}$$

The time period of pendulum T is given by

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{\sqrt{\frac{g}{l}}} \qquad \boxed{T = 2\pi\sqrt{\frac{l}{g}}}$$

Second's pendulum: A simple pendulum whose time period is two seconds is called a second's pendulum.

What is the length of a simple pendulum, which ticks seconds?

The time period of the simple pendulum, which ticks seconds is T = 2S. We take g = 9.8 m/s^2.

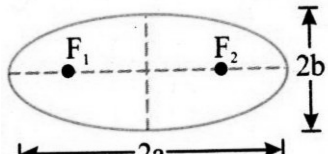
$$T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow T^2 = 4\pi^2\frac{l}{g} \Rightarrow l = \frac{gT^2}{4\pi^2}$$

$$l = \frac{gT^2}{4\pi^2} = \frac{(9.8)(2)^2}{4(3.14)^2} = \frac{\cancel{(9.8)}\cancel{4}}{\cancel{4}\cancel{(9.8)}} = 1m$$

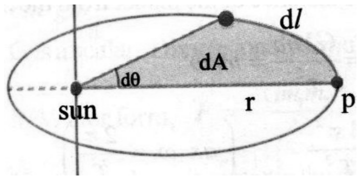
1.

1. Kepler's laws of planetary motion.

Law of orbits:- All planets revolve around sun in elliptical orbits with the sun situated at one of the foci



Law of areas: - The line that joins any planet to the sun equal areas in equal areas in equal intervals of time



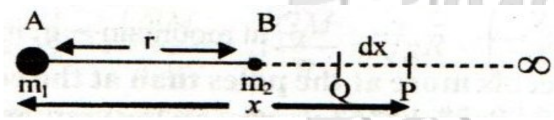
Law of periods: - The square of the time period of revolution of a planet is proportional to cube of the semi-major axis of the ellipse traced out by the planet

$$T^2 \propto R^3$$

2. Define gravitational potential energy and derive an expression for it associated with two particles of masses m_1 and m_2

A) Gravitational potential energy:- The amount of work done in bringing the given body from infinite to that point against the gravitational force Gravitational potential energy.

Expression for gravitational potential energy:
Consider a body of mass m_2 is placed at B in the gravitational of a body of mass m_1. Let 'r' be the distance of separation between two particles.



In order to determine the gravitational potential energy of this system of two particles, let is calculate the work done in moving mass m_1 from infinity to B. When the mass m_1 us at A, the gravitational force of attraction on it due to mass m_2 is given by

$$F = \frac{G m_1 m_2}{x^2}$$

When the mass m_2 moves from A to B, through distance dx then

dw = Force x displacement
dw = F x dx

$$dW = \frac{Gm_1m_2}{x^2} dx$$

Total work done in bringing the body from infinity to point P is given by

$$W = \int_{\infty}^{r} \frac{Gm_1m_2}{x^2} dx$$

$$W = -Gm_1m_2\left[\frac{1}{x}\right]_{\infty}^{r} = -Gm_1m_2\left[\frac{1}{r} - \frac{1}{\infty}\right]$$

$$\boxed{W = -\frac{Gm_1m_2}{r}}$$

3. What is orbital velocity? Obtain an expression for it.

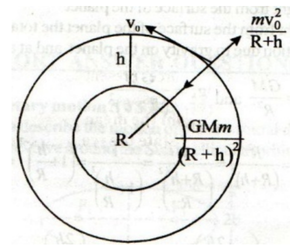
A) **Orbital velocity:-** The minimum velocity required for an object to revolve around a planet in a circular orbit is called orbital velocity

Expression: Consider an object of mass m revolving around planet of mass M and radius R. Let 'h' be the distance of centre of mass of the object from the surface of the planet.

Let V_0 be the horizontal speed of the object when it revolves around the planet in circular orbit

Centripetal force = Gravitational force

$$\frac{mV_0^2}{(R+h)} = \frac{GMm}{(R+h)^2}$$



$$\Rightarrow V_0^2 = \frac{GM}{(R+h)}$$

$$\Rightarrow V_0 = \sqrt{\frac{GM}{(R+h)}}$$

When h is very same when compared to the radius of the planet R, then (R+h) becomes R.

$$\Rightarrow V_0 = \sqrt{\frac{GM}{R}}$$

$$= \sqrt{\frac{gR^2}{R}} \quad \left[\because g = \frac{GM}{R^2} \Rightarrow GM = gR^2\right]$$

$$\boxed{V_0 = \sqrt{gR}}$$

4. What is escape velocity? Obtain an expression for it.

A) **Escape velocity:-** The minimum velocity required for an object escape from the gravitational influence of a planet is known as escape velocity.

Expression:- Consider an object of mass 'm' at rest on the surface of a planet of mass M and radius R.
Gravitational P.E = work done on the body

$$\therefore P.E = F \times R$$

$$= \frac{GMm}{R^2} \times R$$

$$P.E = -\frac{GMm}{R}$$

The minimum speed to be imparted to the bound object at rest is escape velocity V_e

The kinetic energy imparted to the object must be equal and opposite to the potential energy of the system

When it's K.E=P.E

$$\frac{1}{2}mV_e^2 = -\left(\frac{-GMm}{R}\right)$$

$$\Rightarrow \frac{1}{2}\cancel{m}V_e^2 = \frac{GM\cancel{m}}{R} \qquad \Rightarrow V_e = \sqrt{\frac{2GM}{R}}$$

$$= \sqrt{\frac{2gR^2}{R}} \quad \left[\because GM = gR^2\right]$$

$$\boxed{V_e = \sqrt{2gR}}$$

5. Derive an expression for the variation of acceleration due to gravity (a) above and (b) below the surface of the earth:

i) <u>Variation of g with height</u>: Let 'g' be the acceleration due to gravity on the surface of the earth.

Then $g=\dfrac{GM}{R^2}$ ----------(1)

The gravitational force of attraction of the earth on the body is equal to its weight mg_h where g_b is the acceleration due to gravity at height 'h'

$$g_h=\frac{GM}{(R+h)^2}\text{ --------(2)}$$

$$\frac{g_h}{g}=\frac{\cancel{GM}}{(R+h)^2}\times\frac{R^2}{\cancel{GM}}$$

$$\therefore\frac{g_h}{g}=\frac{R^2}{(R+h)^2}=\frac{1}{\frac{(R+h)^2}{R^2}}$$

$$\Rightarrow g_h=\frac{g}{\left(1+\frac{h}{R}\right)^2}=g\left(1+\frac{h}{R}\right)^{-2}$$

If h<<R, then $\boxed{g_h=g\left(1-\frac{2h}{R}\right)}$

Thus the acceleration due to gravity decreases with height

ii) <u>Variation of g with depth</u>: Let g be the acceleration due to gravity at a place on the surface of the earth

Then $g=\dfrac{GM}{R^2}$ ------------------- **(1)**

But the mass of the earth $M=\frac{4}{3}\pi R^3\rho$

$$g=G\frac{\frac{4}{3}\pi R^3\rho}{R^2}=\frac{4}{3}\pi R\rho G\text{------(2)}$$

Consider a body of mass 'm' is at a depth 'd' from the surface of the earth the force on the body will be to the mass of the earth confined in a sphere of radius (R-d) only. Let g_d be the acceleration due to gravity at depth

Then $g=\frac{4}{3}\pi G\rho(R-d)$------(3)

From eq. (2) and (3), we get

$$\frac{g_d}{g}=\frac{\cancel{\frac{4}{3}}\cancel{\pi}\rho(R-d)\cancel{G}}{\cancel{\frac{4}{3}}\cancel{\pi}\rho\cancel{G}R}\qquad\frac{g_d}{g}=\frac{R-d}{R}$$

$$\boxed{\therefore g_d=G\left(1-\frac{d}{R}\right)\text{--------(4)}}$$

Thus the acceleration due to gravity decreases with depth.

2. What is a geostationary satellite? State its uses.

A) If the period of revolution of an artificial satellite is equal to the period of rotation of earth such a satellite is called geostationary satellite"

The time period of geostationary satellite is 24 hours

<u>USES</u>:

i) To study the upper layers of atmosphere

ii) To forecast the changes in atmosphere

iii) To know the shape and size of the earth

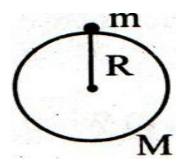
iv) To identify the minerals and natural resources present inside and on the surface of earth

v) Transmit the T.V programmes to distant objects.

3. Derive the relation between acceleration due to gravity (g) at the surface of a planet and gravitational constant(G).

A) Consider a body of mass 'm' placed on the surface of the earth. Consider the earth as a perfect sphere of radius 'R'. suppose the mass of the earth is concentrated at its centre. According to Newton's universal law of gravitation the gravitational force on the body is

$$F=\frac{GMm}{R^2}\text{.......(1)}$$



From Newton's II law, force acting on the body is

$$F=mg\text{........(2)}$$

From (1) and (2) we have

$$\cancel{m}g=\frac{GM\cancel{m}}{R^2}\Rightarrow\boxed{g=\frac{GM}{R^2}}$$

4. Find the torque of a force $7\hat{i}+3\hat{j}-5\hat{k}$ about the origin. The force acts on a particle whose position vector is $\hat{i}-\hat{j}+\hat{k}$

A) Given $\vec{r}=\hat{i}-\hat{j}+\hat{k}$ and $\vec{F}=7\hat{i}+3\hat{j}-5\hat{k}$ then Torque is,

$$\vec{\tau}=\vec{r}\times\vec{F}=\begin{vmatrix}\hat{i}&\hat{j}&\hat{k}\\1&-1&1\\7&3&-5\end{vmatrix}=\hat{i}(5-3)-\hat{j}(-5-7)+\hat{k}(3-(-7))$$

$$=2\hat{i}+12\hat{j}+10\hat{k}$$

1. Define the Stress and explain the types of stress.

A. **Stress:** restoring force per unit cross sectional area is called stress.

Different types stress:

Longitudinal (or) linear (or) tensile stress: When a deforming force is applied to cause a **change in length** of the body is called longitudinal stress.

$$\text{Longitudinal Stress} = \frac{\text{Restoring Force}}{\text{Crossional Area}}$$

Bulk (or) Volume (or) Normal stress: When a deforming force is applied to cause a **change in volume** of the body is called bulk stress.

$$\text{Bulk Stress} = \frac{\text{Restoring Force}}{\text{Crossional Area}} = \left(\frac{F}{A}\right)$$

Shearing (or) tangential stress: When a deforming force is applied to cause a **change in shape** of the body at constant volume, is called shearing stress.

$$\text{Shearing Stress} = \frac{\text{Restoring Force}}{\text{Crossional Area}} = \left(\frac{F}{A}\right)$$

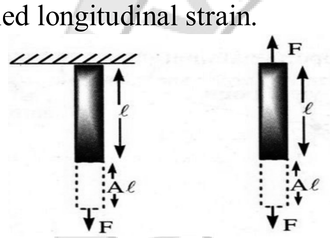
2. Define the Strain and explain the types of strain.

A. **Strain:** The ratio of change dimension to original dimension is called strain.

$$\text{Strain} = \frac{\text{Change in Dimension}}{\text{Original Dimension}}$$

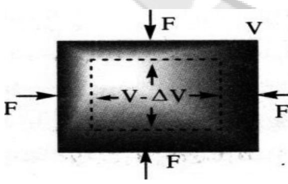
Different types strain:

Longitudinal strain: The ratio of change in length to original length is called longitudinal strain.



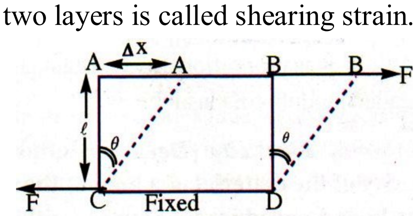
$$\text{Longitudinal Strain} = \frac{\text{Change in Length}}{\text{Original Length}} = \left(\frac{\Delta l}{l}\right) = \left(\frac{e}{l}\right)$$

Bulk strain: The ratio of change in volume to original volume is called bulk strain.



$$\text{Bulk Strain} = \frac{\text{Change in Volume}}{\text{Original Volume}} = \left(\frac{\Delta V}{V}\right) = \left(\frac{e}{V}\right)$$

Shearing strain: The ratio of relative displacement between two layers to perpendicular distance between those two layers is called shearing strain.



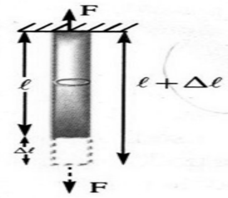
$$\text{Shearing Strain} = \frac{\text{Relative displacement between two layers}}{\text{Perpendicular distance between two layers}}$$

3. Define Young's modulus, Bulk modulus and Rigidity modulus.

A. **Young's modulus of Elasticity(Y):** The ratio of longitudinal stress to longitudinal strain is called young's modulus of elasticity.

$$(Y) = \frac{\text{Longitudinal stress}}{\text{Longitudinal strain}}$$

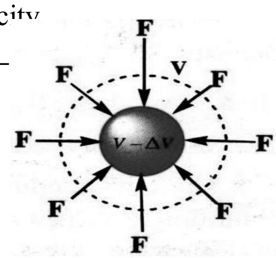
$$= \left(\frac{F/A}{\Delta l/l}\right) = \left(\frac{F}{A} \times \frac{l}{\Delta l}\right)$$



Bulk (or) volume modulus of Elasticity (B): The ratio of volume stress to volume strain is called bulk/volume modulus of elasticity

$$(V) = \frac{\text{Volume stress}}{\text{Volume strain}}$$

$$= \frac{\Delta P}{\left(-\frac{\Delta V}{V}\right)}$$



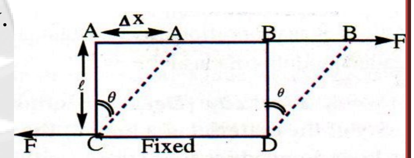
Here Negative sign shows that with increase in pressure the volume decreases.

Here Negative sign shows that with increase in pressure the volume decreases.

Shear (or) Rigidity modulus of Elasticity (B): The ratio of shearing stress to shearing strain is called shear modulus of elasticity.

$$(G) = \frac{\text{Shearing stress}}{\text{Shearing strain}}$$

$$= \frac{F/A}{\theta} = \frac{F}{A.\theta}$$



4. Define modulus of elasticity, stress, strain and Poisson's ratio

A. **Modulus of elasticity (K):** The ratio of stress to strain is called modulus of elasticity.

$$\text{Modulus of Elasticity}(K) = \frac{\text{stress}}{\text{strain}}$$

$\text{S.I Units: } N.m^{-2}$ (or) Pascals

Stress: restoring force per unit cross sectional area is called stress.

$$\text{Shearing Stress} = \frac{\text{Restoring Force}}{\text{Crossional Area}} = \left(\frac{F}{A}\right)$$

$\text{S.I Units: } N.m^{-2}$ (or) Pascals

Strain: The ratio of change dimension to original dimension is called strain.

$$\text{Strain} = \frac{\text{Change in Dimension}}{\text{Original Dimension}}$$

$\text{S.I Units: } N.m^{-2}$ (or) Pascals

Poisson's Ratio (σ)**:** The ratio lateral contraction strain to longitudinal elongation strain is called Poisson's ratio

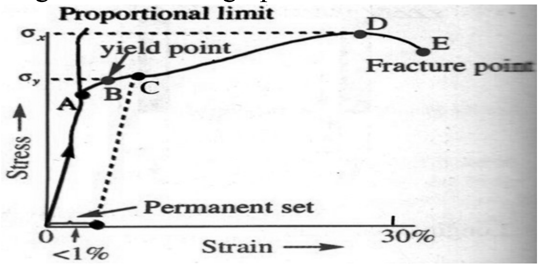
$$(\sigma) = \frac{\text{Lateral contration strain}}{\text{Longitudinal elongation strain}}$$

Theoretical limits of Poisson's ratio are from **-1 to 0.5**

Practical limits of Poisson's ratio are from **0 to 0.5**

4. Describe the behavior of a wire under gradually increasing load?

A. Graph is drawn between strain along X- axis and stress along Y – axis. The graph is shown below



<u>Proportionality limit (A):</u> The stress is directly proportional to the strain and the wire obeys Hooke's law. The point A is called proportionality limit.

<u>Elastic limit (or) Yield Point(B):</u> From A to B, as stress is further increased, the wire does not obey Hook's law at B, The wire regains its original length after removing the stretching force at B. the point B. is called elastic limit.

<u>Permanent set(C):</u> If the stress is further increased the wire does not regain its original length and the length of the wire changes permanently. The point 'C' is called permanent set.

<u>Breaking point(D):</u> When the stress increased, the wire becomes thinner and thinner. When the stress increases to a certain limit the wire breaks. The point 'D' is called breaking point.

<u>Elastic fatigue (or) Fracture point:</u> The state of temporary loss of elastic nature of a body to continuous strain is called elastic fatigue (or) fracture point.

5. Define strain energy and derive the equation for the same.

A. **<u>Strain energy</u>:** The energy stored in a body when stretched is called strain energy.

<u>Expression for strain energy:</u> Let us consider a wire of length 'L' and cross-sectional area 'A'. Let 'X' be the change in length of the wire by the application of stretching force 'F'

$$\text{Youngs modulus} = \frac{\text{Longitudinal Stress}}{\text{Longitudinal Strain}} = \left(\frac{F}{A}\right)\left(\frac{L}{X}\right)$$

To stretch the wire further by **'dx'** the workdone

$$dw = F.dx$$

$$dw = \left(\frac{yAx}{L}\right)dx$$

Total work done to stretch the wire from '0' to 'x' is given by

$$W = \int dw = \int_0^x \left(\tfrac{YAx}{L}\right)dx$$

$$= \tfrac{YA}{L}\int_0^x (x)\,dx = \tfrac{YA}{L}\left(\frac{x^2}{2}\right) = \tfrac{1}{2}\left(\tfrac{YAx}{L}\right)x$$

$$W = \tfrac{1}{2}F.x$$

$$W = \tfrac{1}{2}(\text{stretching force})(\text{elongation})$$

$$\left(\frac{\text{Strain energy}}{\text{Volume}}\right) = \frac{1}{2}\left(\frac{F}{A}\right)\left(\frac{X}{L}\right) = \frac{1}{2}(\text{Stress})(\text{Strain})$$

1. A tungsten wire of length 20cm is stretched by 0.1cm. Find the strain on the wire.

A. Original length = 20cm = 20×10^{-2}m,
Change in length = 0.1cm = 0.1×10^{-2}

$$\text{strain} = \frac{\text{change in length}}{\text{Original length}} = \frac{\Delta l}{l}$$

$$\text{strain} = \frac{0.1\times10^{-2}}{20\times10^{-2}} = \frac{1}{200} = 0.005$$

2. If an iron wire stretched by 1%, what is the strain on the wire?

Original length = 1m, change in length = 1%

$$\text{strain} = \frac{\text{change in length}}{\text{Original length}} = \frac{\Delta l}{l}$$

$$\text{strain} = \frac{1}{1\times100} = \frac{1}{100} = 0.01$$

3. Determine the pressure required to reduce the given volume of water by 2%. Bulk modulus of water is 2.2×10^9 Nm^{-2}.

Original volume = 1, change in volume = -- 2%,
K = 2.2×10^9

$$P = -K\left(\frac{\Delta V}{V}\right)$$

$$P = -2.2\times10^9\left(-\frac{2}{100}\right) = 4.4\times10^9\times10^{-2} = 4.4\times10^7\ Nm^{-2}$$

4. A copper wire 1mm diameter is stretched by applying a force of 10N. Find the stress in the wire

$$\text{stress} = \frac{F}{A} = \frac{F}{\Pi r^2} = \frac{F}{\Pi\left(\frac{D}{2}\right)^2}$$

$$\text{stress} = \frac{10}{\frac{22}{7}\left(\frac{10^{-3}}{2}\right)^2} = \frac{10\times7\times4}{22\times10^{-6}} = \frac{14}{11}\times10^7 = 1.273\times10^7\ N/m^2$$

5. A steel wire of length 20cm is stretched to increase its length by 0.2cm. find the lateral strain in the wire if the Poisson's ratio for steel is 0.19

$$\text{length} = 20cm = 20\times10^{-1}m,\ \Delta l = 0.2cm = 0.2\times10^{-3}m,\ \sigma = 0.9$$

Lateral strain = (σ) longitudinal strain

$$\text{lateral strain} = 0.19\times\frac{2\times10^{-3}}{2\times10^{-1}} = 0.19\times\frac{1}{100} = 0.0019$$

6. A copper cube of side of length 1cm is subjected to pressure of 100 atmospheres. Fine the change in its volume if the bulk modulus of copper 1.4×10^{-2} N/m^2

$$\text{length} = 1cm = 1\times10^{-2}m,\ V = L^3 = 10^{-6}\ m^2,$$

$$P = 100atm = 100\times10^5\ N/m^2,\ K = 1.4\times10\times10^{11}\ N/m^{-2}.$$

$$\text{change in volume } \Delta V = \frac{PV}{K} = \frac{100\times10^5\times10^{-6}}{1.4\times10^{11}} = \frac{10}{14}\times10^{-10}m^3$$

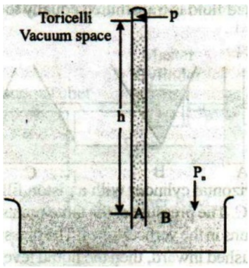
7. A spherical ball of volume $1000cm^3$ is subjected to a pressure of 10 atmospheres. The change in volume is $10^{-2}cm^3$. if the ball is made of iron. Find its bulk modulus.

$$V = 1000cm^3 = 10^{-3}m^3,\ P = 10atm = 10\times10^5 N/m^2,\ \Delta V = 10^{-2}cm^2 = 10^{-8}m^3$$

$$(K) = \frac{PV}{\Delta V} = \frac{10\times10^5\times10^{-3}}{10^{-8}} = 10^{14}\times10^{-3} = 1\times10^{11}N/m^2$$

1. What is atmospheric pressure and how is it determined by using Barometer?

A) The pressure of the atmosphere at any point is equal to the weight of a column of air of unit cross sectional area extending from that point to the top the atmosphere.. At sea level it is 1.013 x 10^5 Pa (1 atm).



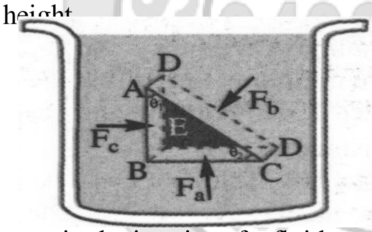
Along glass tube closed at one end and filled with mercury is inverted in to through of mercury this device is known as mercury barometer. The space above the mercury column in the tube contains only mercury vapour whose pressure P is small and it is neglected. The pressure inside the column at point A must equal the pressure at point B

$$p= \rho \text{ gh}$$

Where ρ is the density of mercury And h is the height of the mercury. The experiment is found that the mercury column in the barometer has a height of about 76 cm at sea level equivalent to one atmosphere

2. <u>State Pascal's law and verify it with the help of an experiment</u>:

A) The pressure in fluid at rest is the same at all points if they are in the same height



Consider a small element in the interior of a fluid a rest. The element ABC –DEF is in the form of a right –angled prism the effect of the gravity is the same at all these points

Suppose the fluid exert pressure P_aP_b and P_c on the faces BEFC, ADFC and ADEB respectively. The corresponding normal forces are F_a , F_b and F_c Let A_a, A_b and A_c be the respective areas of the three faces in various directions.

$A_b\sin = A_c \quad \cos=A_a$

(By geometry) thus

$$\frac{F_b \sin\theta_2}{A_b \sin\theta_2} = \frac{F_c}{A_c} \quad \frac{F_b \cos\theta_2}{A_b cos\theta_2} = \frac{F_a}{A_a}$$

$$\boxed{\frac{F_b}{A_b} = \frac{F_c}{A_c} = \frac{F_a}{A_a}}$$

Hence pressure exerted is same in all directions in a fluid at rest. This proves pascals law

3. The density of the atmosphere at sea level is 1.29 kg/m^3. Assume that it does not change with altitude. Then, how high would the atmosphere extend?

A) Atm. Pressure = $h\rho g$

1.01 x 10^5 = h x 1.29 x 9.8 = 7989 m

H = 8 km (approx)

4. Explain surface tension and surface energy:

A) **Surface tension(S):** The force acting per unit length of an imaginary line drawn on the free surface of the liquid acting perpendicular to it is called surface tension.

Surface tension: $T = \frac{F}{l}$; $S.I\ unit; Nm^{-1}$

<u>Dimensional formula</u>:

$$T = \frac{F}{l} = \frac{MLT^{-2}}{L} = ML^0T^{-2}$$

Surface energy (E): The additional potential energy per unit area of the surface film is called surface energy

Surface energy = $\frac{work\ done}{Area}$ S.I unit l/m^2

i) Consider a horizontal liquid film ending in bar free to slide over parallel guides

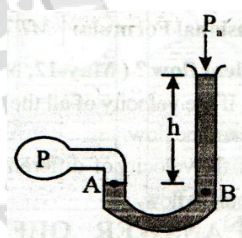
ii) Let the bar be moved a small distance d. Work has been done against an internal force

Let this internal force be F, the work done by the applied force is F.d

S (2dl) =Fd $\qquad$ S= $\frac{F}{2l}$

5. What is gauge pressure and how is a manometer used for measuring pressure difference?

A) Guage pressure us the difference between the actual pressure at a point and the atmospheric pressure



An open –tube manometer is a useful instrument for measuring pressure difference. One end of the tube is open to the atmosphere and other end is connected to the system whose pressure is determined. The pressure P at A is equal to pressure at point B. Let P_a be the atmospheric pressure P-P_a = ρ gh

Gauge pressure is proportional to height h

6. If the diameter of a soap bubble is 10mm and its surface tension is 0.04 Nm^{-1}, Find the excess pressure inside the bubble.

A) Given, Diameter = 10 mm, Radius = 5 mm = 5 x 10^{-3} m, Surface tension T = 0.04 Nm^{-1}

Excess pressure in bubble

$$P = \frac{4T}{r} = \frac{4\times 0.04}{5\times 10^{-3}} = 32 \quad Nm^{-2}$$

7. If the workdone by an agent to from a bubble of radius R is W, then how much energy is required to increase its radius to 2R.

A) Given, workdone to from a bubble of radius R is W.

$W = 8\pi R^2 T \rightarrow (1)$

Energy required to increase its radius from R to 2R

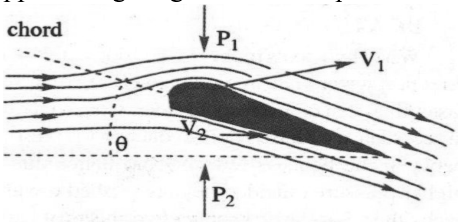
$$= 8\pi T\left[(2R)^2 - (R)^2\right] = 8\pi T\left[3R^2\right]$$

$$= 3\times 8\pi R^2 T = 3W. \left(\because From(1)\ W = 8\pi R^2 T\right)$$

1. Explain dynamic lift with example

: A) **Dynamic lift**: Dynamic lift is the force that acts on a body by virtue of its motion through a fluid

Lift on aircraft wing: The wings of the aeroplane are designed in such a way that the streamlines are clustered on the upper side giving rise to a low pressure

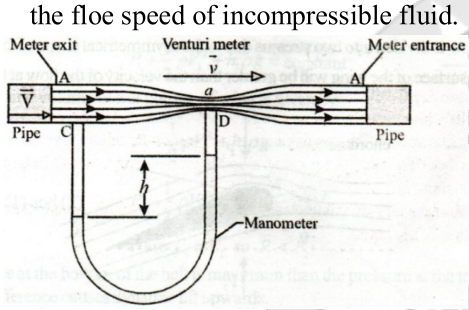


Dynamic lift on air foil

The wing has a curved part on the upper surface. As the aeroplane moves fast on the runway, the velocity of air is more at the upper surface of the wings than at its bottom. Hence the pressure is less on the upper surface of wing and more on the bottom. The difference in pressure produces the required dynamic lift and allows the aeroplane to take off.

2. What is venture-meter? Explain how it is used.

A) **Venturi meter:** The venture –meter is a device to measure the floe speed of incompressible fluid.



i) It consists of a tube with a broad diameter and a small constriction at the middle

ii) A manometer in the form of a U- tube is also attached to it, with one of arm at the broad neck point of the tube and the other at constriction as shown in fig

iii) The manometer contains a liquid of density ρ_m

iv) The pressure difference causes the fluid in the U-tube connected at the narrow neck to rise incomparison to the other arm

v) Filter pumps, sprayers used for perfumes, carburetor of automobile has used on the principle.

3. What is Reynold's number? What is its significance.

A) Reynold's number is a dimensionless number, whose value gives an approximate idea whether the flow is steady or turbulent. This number is called Reynold's number.

$$\boxed{R_e = \frac{\rho v d}{\eta}}$$

Where 'ρ' is the density of the fluid flowing with speed 'v' and 'd' is the dimension of the pipe. 'η' is the coefficient of viscosity of the fluid.

Importance: -

1. $R_e \ll 1000$ The flow is streamlined flow.

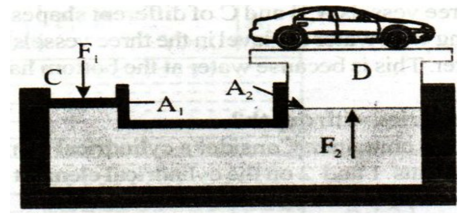
2. $R_e \gg 1000$ The flow is turbulent flow.

3. R_e lies between 1000 and 2000 The flow is unsteady and it may change laminar to turbulent flow.

4. Explain hydraulic lift and hydraulic brakes:

A) Hydraulic lift and hydraulic brakes are based on pascal's law

Hydraulic lift: Here C and D are two cylinder of difference areas of cross section. They are connected to each circle with a pipe E. Each cylinder is provided with air light friction less piton. Let A_1, A_2 be the areas of cross section of the piston at C and D ($A_1 << A_2$)



The cylinders are filled with an incompressible liquid. Let f be the applied force at C pressure exerted on the liquid

$$P = \frac{f}{a} \text{ …………………… (1)}$$

According to pascals law, this pressure is transmitted to piston of cylinder D. Upward force at D will be

$$F = PA = \frac{f}{a} A = f\frac{A}{a} \text{ …………….. (2)}$$

As A > > a F > > f

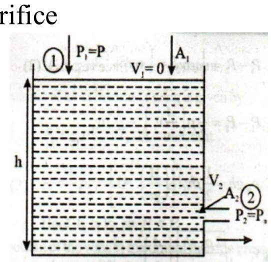
∴ Heavy load placed on the larger piston is easily lifted

Hydraulic Brakes:

When the brake pedal is pressed, the piston (P) of the after cylinder is pushed inwards. There will be increased pressure on solid at P. Which is transmitted equally P_1 and P_2 of wheel cylinder in accordance with pascal law. Due to which P_1 and P_2 move outwards. Breakshoes to move away from each other which in turn press against the inner of the wheel. The brake become

5. What is Torricelli's law? Explain how the speed of efflux is determined with an experiment.

A) **Torricelli's law:** The efflux velocity if a liquid through an orifice (small hole) of a vessel is equal to the velocity acquired by a freely falling body from a height which is equal to that of liquid from the orifice



Let P_1, v_1 and h_1 be the pressure, velocity and liquid level at the surface of the liquid

Let P_2, v_2 and h_2 be the corresponding values at the orifice

Let ρ be the density of the liquid

According to Bernoulli's equation At(A) and (O)

$$(P+\rho gh+O)_{atA} = [p+0+\frac{1}{2}\rho v^2]_{atO}$$

$$P + \rho gh = P + \frac{1}{2}\rho v^2$$

$$= Pgh = \frac{1}{2} Pv^2 \qquad v = \sqrt{2gh}$$

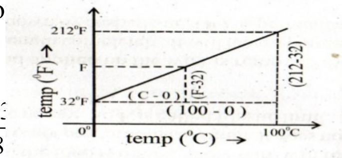
1. Explain Celsius and Fahrenheit scales of temperature. Obtain the relation between Celsius and Fahrenheit scales of temperature.

A. **Celsius scale: -** In the Celsius scale of temperature, the lower fixed point (ice) is taken as 0^0C. The upper fixed point (steam) is taken as 100^0C. The interval between lower and upper fixed point is divided into 100 equal parts, each one corresponding to 1^0C.

Fahrenheit scale:- In the Fahrenheit scale of temperature, the lower fixed point (ice) is taken as 32^0F. The upper fixed point (steam) is taken as 212^0F. The interval between lower and upper fixed point is divided into 180 equal parts, each o

$$\text{Slope} = \frac{Y_2 - Y_1}{X_2 - X_1} = \text{Constant}$$

$$\frac{C-0}{100-0} = \frac{F-32}{212-32} \Rightarrow \frac{C}{100} = \frac{F-}{18}$$



This is relation between 'C' and 'F'

2. Explain conduction, convection and radiation with examples.

A. **Conduction**: - The process of transmission of heat from one place to another place **without actual moment of particles** of the medium is called conduction.

Ex: - Conduction takes place through solids.

Convection: - The process of transmission of heat from one place to another place **with actual moment of particles** of the medium is called convection.

Ex: - Sea breeze, trade wind ext.,

Radiation: - The process of transmission of heat from one place to another place **without requirement** of the medium is called radiation.

Ex: - Earth receives heat radiations from the sun.

3. Pendulum clocks generally go fast in winter and slow in summer. Why?

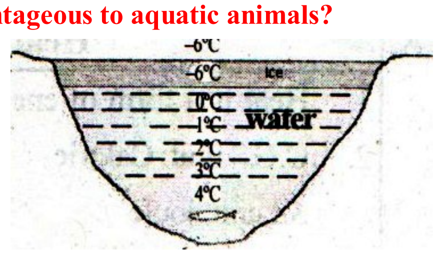
A. $T = 2\Pi\sqrt{\frac{l}{g}}$, $T \, \alpha \sqrt{l}$

(a) In winter, due to decrease in temperature, length of the pendulum decreases, time period decreases and clock gains time. Hence it goes fast in winter.

(b) In summer, due to increase in temperature, length of the pendulum increases, time period increases and clock looses time. Hence it goes slowly in summer.

4. In what way is the anomalous behavior of water advantageous to aquatic animals?

A.



(a) Anomalous behavior : Water attains maximum density at 4^0C.

(b) So, when temperature increases from 0^0C to 4^0C water contract instead of expansion. This is called anomalous behavior of water.

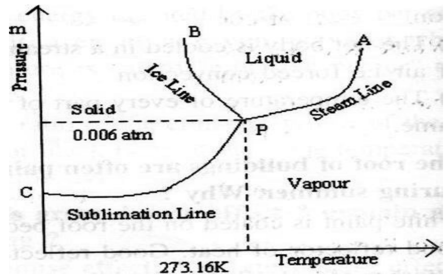
(c) During winter, when the temperature of the atmosphere falls below 0^0C, the surface of lakes freezes to ice.

(d) But ice is bad conductor of heat. Under the frozen upper layers, the water remains in its liquid form and does not freeze. Thus aquatic animals are survived.

5. Write the short notes on Triple point of water?

A. **Definition**: - The pressure and temperature at which the solid, liquid and vapor can co – exist in equilibrium is called triple point of water.

Its coordinates are (273.5 K, 4.58 atm)



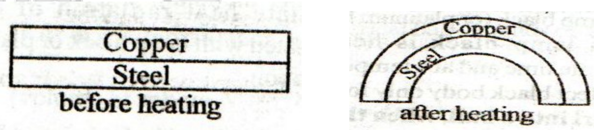
Ice (fusion) line PB: - The line PB is called ice line. Here ice and water are in equilibrium. It has negative slope. Hence melting point of ice decreases within increase in pressure. The substance will exist in the solid state to the left and in liquid state to the right.

Steam line PA: - The line PA is called steam line. Here water and vapor are in equilibrium. It has positive slope. Hence boiling point of water increases with increase of pressure. The substance will exist above the curve in liquid state and below the curve in vapor state.

Sublimation (or) Hoar frost line PC: -The line PC is called sublimation line. Here solid and vapor are in equilibrium. It has positive slope. The substance will exist above the curve in solid state and below the curve in vapor state.

6. Two identical rectangular strips one of copper and the other of steel are riveted together to form a bimetallic strip. What will happen on heating.

A.



(a) Consider a bimetallic strip made of copper and steel of same length. 'l' at room temperature

(b) When a bimetallic strip is heated copper **expands** more than the steel. So, the bimetallic strip bends with the copper on convex side and steel on concave side.

(c) When a bimetallic strip is cooled copper **contract** more than the steel. So, the bimetallic strip bends with the copper on concave side and steel on convex side.

7. What is the temperature for which the readings on Kelvin and Fahrenheit scales are same?

A. Given $F = K = x$

$$\left(\frac{K-273}{100}\right) = \left(\frac{F-32}{180}\right) \Rightarrow \frac{x-273}{100} = \frac{x-32}{180}$$

$$9(x-273) = 5(x-32)$$

$$9x - 273 \times 9 = 5x - 32 \times 5$$

$$9x - 5x = 2457 - 160$$

$$4x = 2297$$

$$x = \frac{2297}{4} = 574.25^0$$

7. State boyle's law and Charles law. Derive ideal gas equation. Which of the laws is better for the purpose of thermometer and why?

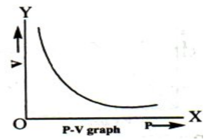
A. **Boyle's Law**:- At constant temperature, the volume of a given mass of gas inversely proportional to its pressure.

$$P \alpha \left(\frac{1}{V}\right) (\text{At constant temperature})$$

$$P = K\left(\frac{1}{V}\right)$$

$$PV = K$$

$$P_1V_1 = P_2V_2$$



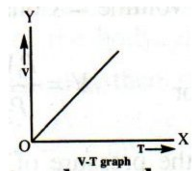
Charles Law:- At constant pressure, the volume of a given mass of a gas directly proportional to its absolute temperature.

$$V \alpha (T) (\text{At consstant pressure})$$

$$V = K(T)$$

$$\frac{V}{T} = K$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$



Ideal gas:- A gas which obeys Boyle's law and Charles laws at all temperatures and pressures is called ideal gas

Derivation for the Ideal gas Equation:- Consider and ideal gas of mass 'm' having pressure P_1, volume V_1, and absolute temperature T_1 . Let the final values of pressure P_2, volume V_2 and temperature T_2 of the gas.

$$\boxed{\frac{P_1V_1}{T_1}} \xrightarrow{\text{Boyle's law}} \boxed{\frac{P_2V}{T_1}} \xrightarrow{\text{Charles law}} \boxed{\frac{P_2V_2}{T_2}}$$

According to Boyles law, Keeping temperature of the gas constant, pressure is changed from P_1 to P_2, let volume changes from V_1 to V_0

$$P_1V_1 = P_2V_0 \qquad (OR) \qquad V_0 = \frac{P_1V_1}{P_2} \;............(1)$$

According to Charles law, Keeping the pressure of the gas constant, if the temperature is changed from T_1 to T_2, let the volume changes from V_0 to V_2.

$$\frac{V_0}{T_1} = \frac{V_2}{T_2} \qquad (or) \qquad V_0 = \frac{T_1}{T_2}V_2 \;...........(2)$$

From the equation (1) and (2)

$$\frac{P_1V_1}{P_2} = \frac{T_1}{T_2}V_2 \Rightarrow \frac{P_1V_1}{T_1} = \frac{P_1V_2}{T_2} \qquad \frac{PV}{T} = r$$

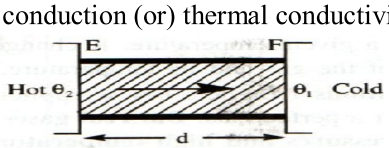
'r' is the constant for 1gm of gas at S.T.P. called gas constant 1gm. Mole of gas is considered, 'r' is replaced by 'R'

$$\frac{PV}{T} = R \qquad\qquad PV = RT$$

Charles law is better for the purpose of thermometry. At constant pressure, volume is directly proportional to absolute temperature. And at constant volume, pressure is directly proportional to absolute temperature.

8. Explain thermal conductivity and coefficient of thermal conductivity.

A. **Thermal conductivity**:- The process of transfer of heat through a material without any actual movement of molecules is called conduction (or) thermal conductivity.



Consider a rectangular slab of area 'A'. it has two end faces 'E' and 'F', maintained at temperatures θ_2 and θ_1 ($\theta_2 > \theta_1$) Let 'Q' be the amount of heat transmitted by conduction between the faces 'E and 'F' separated by the distance 'd' time 't'. the amount of heat flowing between the two faces.

1) Directly proportional to the area of cross section (A).

$$Q \alpha (A)--------(1)$$

2) Directly proportional to the temperature difference ($\theta_2 - \theta_1$) between the two faces.

$$Q \alpha (\theta_2 - \theta_1)------(2)$$

3) Directly proportional to the time for which the heat flows

$$Q \alpha (t)------(3)$$

4) Inversely proportional to the distance (d) between the faces.

$$Q \alpha \left(\frac{1}{d}\right)------(4)$$

From (1), (2), (3) and (4)

$$Q \alpha \frac{(A)(\theta_2-\theta_1)(t)}{d} \quad (OR) \quad Q = \frac{K(A)(\theta_2-\theta_1)(t)}{d}$$

The rate of flow of heat

$$\frac{Q}{t} = \frac{K(A)(\theta_2-\theta_1)}{d}$$

K is called co-efficient of thermal conductivity

Co-efficient of thermal conductivity:- The quantity of heat flowing through unit area of the substance per unit time per unit temperature gradient.

a) CGS unit of 'K' is **cal s^{-1} cm^{-1} $^0C^{-1}$**

b) SI unit of 'K' is **J s^{-1} m^{-1} K^{-1}**

c) Dimensional formula of 'K' is [$M L T^{-3} K^{-1}$]

9. A copper bar of thermal conductivity 401w/(mk) has one end at 104^0C and the other end at 24^0C The length of the bar is 0.10m and the cross sectional area is $1.0\times10^{-6}m^2$ what is the ratio of heat conduction along the bar?

A. K = 401w/(mk), A = $1.0\times10^{-6}m^2$, d = 0.10m

$T_1 = 104^0C$, $T_2 = 24^0C$,

The rate of flow of heat

$$\frac{Q}{t} = \frac{K(A)(\theta_2-\theta_1)}{d} = \frac{401\times10^{-6}(104-24)}{0.10}$$

$$401\times10^{-5}\times80 = 32080\times10^{-5}\,J/s \quad = 0.32080\,J/s$$

10. State and explain Newton's law of cooling state the conditions under which Newton's law of cooling is applicable

A. **Statement**: - The rate of loss of heat of hot body is directly proportional to the temperature difference between the body and its surroundings provided the temperature difference is small and the nature of the reading surface remains same.

If $\frac{dQ}{dt}$ is the rate of loss of heat of hot body at a temperature θ and θ_0 is the surrounding temperature

$$-\frac{dQ}{dt} \alpha (\theta - \theta_0) (-\text{Ve Sign indicates loss of heat})$$

$$-\frac{dQ}{dt} = K(\theta - \theta_0)-----(1)$$

Where 'K' is the constant proportionality.

If 'm' is the mass of the body and 'S' is the specific heat of the body. If temperature falls by small amount dθ than dQ = ms dθ

$$\text{Loss of heat } \frac{dQ}{dt} = ms\frac{d\theta}{dt}-----(2)$$

From equations (1) and (2)

$$ms\frac{d\theta}{dt} = K(\theta - \theta_0) \qquad \boxed{\Rightarrow \frac{d\theta}{dt} = \frac{K}{ms}(\theta - \theta_0)}$$

$\frac{K}{ms}$ is constant

1. Explain reversible and irreversible processes Describe the working of Carnot engine Obtain an expression for the efficiency.

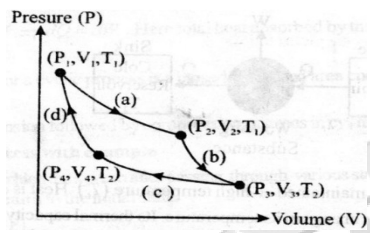
A. **Reversible Process: -** A process that can be retraced back in the opposite direction in such a way that the system passes through the same states as in the direct process and finally the system and the surroundings return to their original states is called a reversible process.

Ex:- Melting of ice and vaporization of water.

Irreversible processes:- A process that cannot be retraced back in the opposite direction is called an irreversible process.

Ex: - Free expansion of a gas and work done against friction.

Carnot's Engine: - A reversible heat engine operating between two different temperatures is called a Carnot engine.



Isothermal Expansion(1 – 2) : Isothermal expansion of the gas taking its state from (P_1,V_1,T_1) to (P_2,V_2,T_1) The heat **absorbed** by the gas (Q_1) from the reservoir at temperature T_1 is equal to the work done by the gas and is given by

$$\boxed{W_{1\to 2} = Q_1 = nRT_1\log_e\left(\frac{V_2}{V_1}\right) \text{------} (1)}$$

Adiabatic Expansion (2 – 3): Adiabatic expansion of the gas from (P_2,V_2,T_1) to (P_3,V_3,T_2) work done by the gas and is given by

$$\boxed{W_{2\to 3} = nR\left(\frac{T_1-T_2}{\gamma-1}\right) \text{-------} (2)}$$

Isothermal Compression(3 – 4) : Isothermal compression of the gas taking its state from (P_3,V_3,T_2) to (P_4,V_4,T_2) The heat **released** by the gas (Q_2) from the reservoir at temperature T_2 is equal to the work done by the gas and is given by

$$\boxed{W_{3\to 4} = Q_2 = nRT_2\log_e\left(\frac{V_4}{V_3}\right) = -nRT_2\log_e\left(\frac{V_3}{V_4}\right) \text{------} (3)}$$

Adiabatic Compression(4 – 1): Adiabatic compression of the gas from (P_4,V_4,T_2) to (P_1,V_1,T_1) work done by the gas and is given by

$$\boxed{W_{4\to 1} = nR\left(\frac{T_2-T_1}{\gamma-1}\right) = -nR\left(\frac{T_1-T_2}{\gamma-1}\right) \text{-------} (4)}$$

Total work done by the gas in one complete cycle is

$$W = W_{1\to 2} + W_{2\to 3} + W_{3\to 4} + W_{4\to 1}$$

$$W = nRT_1\log_e\left(\frac{V_2}{V_1}\right) + nR\cancel{\left(\frac{T_1-T_2}{\gamma-1}\right)} - nRT_2\log_e\left(\frac{V_3}{V_4}\right) - nR\cancel{\left(\frac{T_1-T_2}{\gamma-1}\right)}$$

$$W = nRT_1\log_e\left(\frac{V_2}{V_1}\right) - nRT_2\log_e\left(\frac{V_3}{V_4}\right)$$

Total work done = Total heat absorbed **$W = Q_1 - Q_2$**

$$\eta = \frac{W}{Q} = \frac{Q_1-Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1} \text{------} (5)$$

Substitute equation(1) &(3) in equation (5)

$$\eta = 1 - \frac{nRT_2\log_e\left(\frac{V_3}{V_4}\right)}{nRT_1\log_e\left(\frac{V_2}{V_1}\right)}$$

Adiabatic expansion (2 – 3):-

$$T_1V_2^{\gamma-1} = T_2V_3^{\gamma-1} \text{----} (6)$$

Adiabatic compression (4 – 1):-

$$T_1V_1^{\gamma-1} = T_2V_4^{\gamma-1} \text{----} (7)$$

Dividing equation (6) by (7)

$$\left(\frac{V_2}{V_1}\right)^{\gamma-1} = \left(\frac{V_3}{V_4}\right)^{\gamma-1} (\text{or}) \left(\frac{V_2}{V_1}\right) = \left(\frac{V_3}{V_4}\right) \text{----} (8)$$

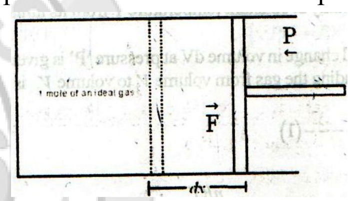
From equations (5) & (8)

$$\eta = \frac{nRT_1\log_e\left(\frac{V_2}{V_1}\right) - nRT_2\log_e\left(\frac{V_2}{V_1}\right)}{nRT_1\log_e\left(\frac{V_2}{V_1}\right)}$$

$$\eta = \frac{\cancel{nR\log_e\left(\frac{V_2}{V_1}\right)}}{\cancel{nR\log_e\left(\frac{V_2}{V_1}\right)}}\left(\frac{T_1-T_2}{T_1}\right) \Rightarrow \eta = \left[1 - \frac{T_2}{T_1}\right]$$

2. Derive a relation between the two specific heat capacities of gas on the basis of first law of thermodynamics

A) 1) Consider one mole of an ideal gas contained in a cylinder provided with a frictionless piston



2) Let A be the area of piston and P,V and T be the pressure, volume and temperature of the gas respectively.

3) When the gas is heated at constant volume so that it's temperature increases by 'dT' the heat supplied dQ is utilized to increase the internal energy of the gas only.

$dQ = dU = 1\,(C_V)\,dT$

$dU = 1\,(C_V)\,dT = C_V\,dT$...............................(i)

4) When the gas is heated at constant pressure it's temperature increases thorugh dT the heat supplied is dQ is utilized to increase the internal energy dU and to do external work dW by displacing the piston through a distance dx.

$dQ = 1\,(C_P)\,dT = C_P\,dT$ ....(ii)

From the first law of thermodynamics , $dQ' = dU + dW$

$C_P\,dT = C_V\,dT + dW$………………..(iii)

Let F is the force acting on the piston and dx is the distance moved. Then workdone

$dW = F\,dx$……………..(iv)

Let P is the atmospheric pressure outside the piston. Then force on the piston is given by

$F = PA$ ………………….(v)

$dW = PA\,dx = PdV$ (or) (or) $C_pdT = C_vdT + PdV$

(or) $(C_p - C_v)dT = PdV$ ………………..(vi)

From ideal gas equation $PV = RT$ $pdV = RdT$……(vii)

From (vi) and (vii)

$$(C_p - C_v)dT = RdT$$

$$(\text{or})\ C_p - C_v = R$$

1. Obtain and expression for the work done by an ideal gas during isothermal change.

A) **Isothermal change:** - Changes in pressure and volume in such a way that temperature remains constant are called isothermal changes.

Let the gas expands isothermally at constant temperature T from its initial state (P_1, V_1) to the final state (P_2,V_2)

The work done during a small change in volume dV at pressure 'P' is given by dW=PdV

The total work done in expanding the gas from volume V_1 to volume V_2 is given by

$$W = \int_{V_1}^{V_2} dW = \int_{V_1}^{V_2} PdV ----(1)$$

From ideal gs equation , PV= nRT

$$\Rightarrow P = \frac{nRT}{V} -----(2)$$

Substituting equation (2) in (1)

$$W = \int_{V_1}^{V_2} n\frac{RT}{V} dV = nRT\int_{V_1}^{V_2} \frac{1}{V} dV \left[\because \int \frac{1}{x}dx = \log_e x\right]$$

$$W = nRT\left[\log_e V\right]_{V_1}^{V_2} = nRT\left[\log_e V_2 - \log_e V_1\right]$$

$$\boxed{W = nRT\log_e\left(\frac{V_2}{V_1}\right) = 2.303\,nRT\log_{10}\left(\frac{V_2}{V_1}\right)}$$

2. Obtain an expression for the work done by an ideal gas during adiabatic change

A) **Adiabatic change:-** Changes in pressure and volume in such a way that no exchange of heat takes place between the system and the surroundings are called adiabatic change

Let the work done during a small change in volume dV at pressure 'P' is given by dW = PdV

The total work done in expanding the gas from volume (V_1) to volume (V_2) is $W = \int_{V_1}^{V_2} PdV -----(1)$

For an adiabatic process PV^{γ} =constant (K) and

$$P = \frac{K}{V^{\gamma}} ------(2)$$

Substituting equation (2) in (1)

$$W = \int_{V_1}^{V_2} \frac{K}{V^{\gamma}} dV = \int_{V_1}^{V_2} KV^{-\gamma} dV = K\left|\frac{V^{-\gamma+1}}{-\gamma+1}\right|_{V_1}^{V_2} \quad \left(\because \int x^n dx = \frac{x^{n-1}}{n+1}\right)$$

$$W = \frac{K}{-\gamma+1}\left[V_2^{-\gamma+1} - V_1^{-\gamma+1}\right]$$

$$W = \frac{1}{-\gamma+1}\left[KV_2^{-\gamma+1} - KV_1^{-\gamma+1}\right]$$

$$W = \frac{1}{-\gamma+1}\left[P_2V_2^{\gamma}V_2^{-\gamma+1} - P_1V_1^{\gamma}V_1^{-\gamma+1}\right] \quad \left(\because P_1V_1^{\gamma} = P_2V_2^{\gamma} = K\right)$$

$$W = \frac{1}{-\gamma+1}\left[P_2V_2 - P_1V_1\right]$$

$$W = \frac{1}{\gamma-1}\left[P_1V_1 - P_2V_2\right]$$

$$W = \frac{1}{\gamma-1}\left[nRT_1 - nRT_2\right] \quad \left(\because PV = nRT \text{ and } P_1V_1 = nRT_1, P_2V_2 = nRT_2\right)$$

$$\boxed{W = \frac{nR}{\gamma-1}\left[T_1 - T_2\right]}$$

3. State second law of thermodynamics. How is heat engine different from a refrigerator?

A) **Second law of thermodynamics:-** Second law of thermodynamics consists of two statements. It gives the direction of flow of heat.

I. **Kelvin –Plank statement:** No process is possible whose sole result is the absorption of heat from a reservoir and the complete conversion of the heat into work

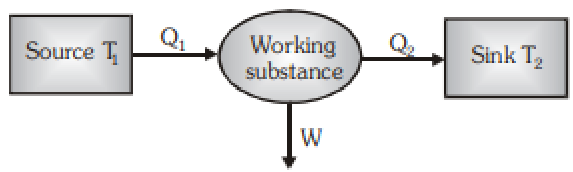
(OR)

It is impossible to construct ideal heat engine

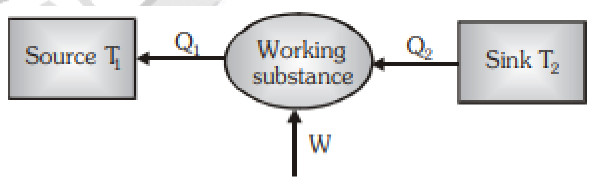
II. **Clausius statement:** No process is possible whose sole result is the transfer of heat from a colder object to a hotter object.

(OR)

It is impossible to construct an ideal refrigerator



HEAT ENGINE
1. Heat engine converts heat into work.
2. The working substance absorbs heat (Q_1) from an external reservoir at high temperature(T_1)
3. The working substance rejects heat (Q_2) to cold reservoir at lower temperature (T_2)
4. Here, work (W) is done by the system.
5. The efficiency (η) of a heat engine is $\eta = \frac{W}{Q_1} = 1 - \frac{Q_2}{Q_1}$
6. η is less than 1



REFRIGERATOR
1. This is a heat pump which is the reverse of a heat engine
2. The working substance absorbs heat (Q_2) from the clod reservoir at temperature (T_2)
3. The working substance rejects heat (Q_1) to hot reservoir at temperature (T_1)
4. Here, work done on the system (refrigerant)
5. The coefficient of performance of a refrigerator $\alpha = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2}$
6. α is greater than 1.

1. Explain the kinetic interpretation of temperature

A) From kinetic theory of gases, average kinetic energy of a gas molecule is $\frac{1}{2}mv^2 = \frac{3}{2}KT$ (or) $\frac{1}{2}mv^2 \alpha T$

Thus, Average kinetic energy of a gas molecule is directly proportional to its absolute temperature of the gas. Thus the temperature of the gas gives the measure of average kinetic energy of the gas molecular.

If T = 0, then $\frac{1}{2}mv^2 = 0$ (or) v = 0 since $m \neq 0$

Therefore, absolute zero is that temperature at which the molecular motion stops.

2. How specific heat capacity of mono atomic, diatomic and poly atomic gases can be explained on the basis of Law of equipartition of energy?

A) **1. Mono atomic gas:** A mono atomic gas molecule has 3 degrees of freedom.(f =3)

The total internal energy U of a mole of a gas is

$$U = \frac{f}{2}KT \times N_A = \frac{f}{2}RT.\ (KN_A = R) \Rightarrow \frac{dU}{\cancel{dT}} = \frac{f}{2}R\cancel{T} = \frac{f}{2}R$$

The molar specific heat at const. volume is

$$C_V = \frac{f}{2}R = \frac{3}{2}R$$

For an ideal gas

$$C_P - C_V = R \Rightarrow C_P = C_V + R = \frac{3}{2}R + R$$

$$\therefore C_P = \frac{5}{2}R \qquad \boxed{\gamma = \frac{C_P}{C_V} = \frac{5}{3}}$$

2. Diatomic gas: A Diatomic gas molecule has 5 degrees of freedom 3 – translational and 2 – Rotational. (f = 5)

The total internal energy U of a mole of a gas is

$$U = \frac{f}{2}KT \times N_A = \frac{f}{2}RT.\ (KN_A = R) \Rightarrow \frac{dU}{\cancel{dT}} = \frac{f}{2}R\cancel{T} = \frac{f}{2}R$$

The molar specific heat at const. volume is

$$C_V = \frac{f}{2}R = \frac{5}{2}R$$

For an ideal gas $C_P - C_V = R \Rightarrow C_P = C_V + R = \frac{5}{2}R + R$

$$C_P = \frac{7}{2}R \qquad \boxed{\gamma = \frac{C_P}{C_V} = \frac{7}{5}}$$

3. Polyatomic gas: A polyatomic molecular has 6 degrees of freedom 3 – translational, and 3 – rotational. (f = 6)

The total internal energy U of a mole of a gas is

$$U = \frac{f}{2}KT \times N_A = \frac{f}{2}RT.\ (KN_A = R) \Rightarrow \frac{dU}{\cancel{dT}} = \frac{f}{2}R\cancel{T} = \frac{f}{2}R$$

molar specific heat at constant volume is

$$C_V = \frac{f}{2}R = \frac{6}{2}R = 3R$$

For an ideal gas

$$C_P - C_V = R \Rightarrow C_P = C_V + R = 3R + R$$

$$C_P = 4R \qquad \boxed{\gamma = \frac{C_P}{C_V} = \frac{4}{3}}$$

3. Explain the concept of absolute zero temperature on the basis of kinetic theory?

A) From kinetic theory of gases, average kinetic energy of a gas molecule is given by $\frac{1}{2}mv^2 = \frac{3}{2}KT \Rightarrow \frac{1}{2}mv^2 \alpha T$

Thus, Average kinetic energy of a gas molecule is directly proportional to the absolute temperature of the gas. Thus the temperature of the gas gives the measure of average kinetic energy of the gas molecule.

If T = 0, then $\frac{1}{2}mv^2 = 0$ (or) v = 0 since $m \neq 0$

Therefore, absolute zero is that temperature at which the molecular motion stops.

6. What is the ratio of rms speed of oxygen and hydrogen molecules at the same temperature?

A) For a gas rms Velocity $V = \sqrt{\frac{2RT}{M}}$ (or) $V \alpha \frac{1}{\sqrt{M}}$ at constant temperature (or) $\frac{V_{O_2}}{V_{H_2}} = \sqrt{\frac{M_{H_2}}{M_{O_2}}} = \sqrt{\frac{2}{32}} = \frac{1}{4}$

The Ratio of rms speeds of oxygen to hydrogen is 1 : 4

7. Four molecules of gas have speeds 1,2,3 and 4 km/s. Find rms speed of the gas molecules.

A) For the gas rms speed $(V) = \sqrt{\frac{V_1^2 + V_2^2 + V_3^2 + V_4^2}{4}}$;

$$V = \sqrt{\frac{1^2 + 2^2 + 3^2 + 4^4}{4}} = \sqrt{\frac{1+4+9+16}{4}} = \sqrt{\frac{30}{4}}$$

$$V = \sqrt{7.5} = 2.74\ km/s$$

10. If the absolute temperature of a gas is increased to 3 times, what will be the increase in rms velocity of the gas molecule?

A) $V_{rms} = \sqrt{\frac{3K_BT}{m}}$ $\quad V_{rms} \alpha \sqrt{T}$ and given $T_1 = T$, $T_2 = 3T$

$$\frac{V^1_{rms}}{V_{rms}} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{3\cancel{T}}{\cancel{T}}} \qquad V^1_{rms} = \sqrt{3}V_{rms}$$

Increase in RMS velocity =

$$V^1_{rms} - V_{rms} = \sqrt{3}V_{rms} - V_{rms} = V_{rms}(1.732 - 1) = 0.732V_{rms}$$

8. Find the increase in temperature of aluminum rod if its length is increased by 1% (α for aluminum = $25 \times 10^{-6}/^0C$)

A) Give that $\alpha = 25 \times 10^{-6}/^0C$ length increased by 1%

$$l_2 = l_1 + l_1(1\%) \Rightarrow l_2 + \frac{l_1}{100} = \frac{101 l_1}{100} \Rightarrow \frac{l_2}{l_1} = \frac{101}{100}$$

$$l_2 = l_1\left[1 + \alpha(t_2 - t_1)\right] \Rightarrow \frac{l_2}{l_1} = 1 + \alpha(t_2 - t_1)$$

$$\frac{l_2}{l_1} - 1 = \alpha(t_2 - t_1) \Rightarrow \alpha(t_2 - t_1) = \frac{101}{100} - 1$$

$$\alpha(t_2 - t_1) = \frac{101 - 100}{100} \Rightarrow \alpha(t_2 - t_1) = \frac{1}{100}$$

$$(t_2 - t_1) = \frac{1}{100 \times \alpha} = \frac{1}{100 \times 25 \times 10^{-6}} = \frac{\cancel{10000}}{\cancel{25}}$$

$$(t_2 - t_1) = 400^0 C$$

14. Kinetic theory of Gases (4 Marks)

1. Derive an expression for the pressure of an ideal gas in a container from kinetic theory and hence give kinetic interpretation of temperature?

A) Consider a cubical vessel each of side l as shown in the figure

Then volume of the vessel $V=l^3$

Let m is the mass of each molecule and N is the total number of molecules in the gas.

Consider a molecule of the gas moving with velocity $\bar{v}$.

Let $\bar{v}_x, \bar{v}_y$ and $\bar{v}_z$ are the rectangular components of $\bar{v}$ along OX, OY and OZ, then $v^2=v_x^2+v_y^2+v_z^2$……….(1)

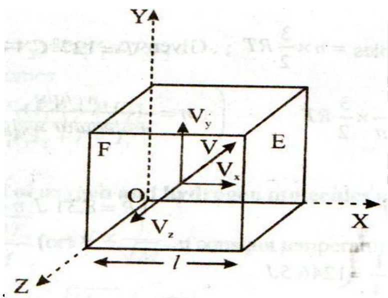
Consider the molecule with horizontal component of velocity $\bar{v}_x$ colliding the face 'E' of the vessel elastically

Before collision momentum of the molecule $=m\bar{v}_x$

After collision momentum of the molecule $= -m\bar{v}_x$

Change in momentum of the molecule

$$\Delta P = -m\bar{v}_x - \left(m\bar{v}_x\right) = -2m\bar{v}_x$$



Momentum imparted to the face 'E' of the vessel by one collision of the molecule $= 2m\bar{v}_x$

Suppose the molecule come back and colliding the face 'F' and agin collinding face 'E' in time interval Δ t.

$\therefore \Delta t = \dfrac{2l}{v_x}$; where $2l$ is distance between E and F

The force exerted on the face 'E' due to one molecule is given by

$$F_x = \frac{2mv_x}{\Delta t} = \frac{2mv_x}{2l/v_x} = \frac{mv_x^2}{l}$$

Now the total force exerted on 'E' by all the molecules with component of velocity along OX is given by

$$F_x = \sum \frac{m\vec{v}_x^2}{l} = \frac{m}{l}\sum \vec{v}_x^2$$

Now pressure exerted by rge above force on face 'E' is given by

$$P_x = \frac{F_x}{area\, of\ face\, E} = \frac{\frac{m}{l}\sum \vec{v}_x^2}{l^2} = \frac{m}{l^3}\sum \vec{v}_x^2 = \frac{m}{V}\sum \vec{v}_x^2$$

Similary, $P_y = \dfrac{m}{V}\sum \vec{v}_y^2$ and $P_z = \dfrac{m}{V}\sum \vec{v}_z^2$

Sice the pressure exerted by gas molecules is the same in all the directions, we have

$P_x = P_y = P_z = P(say)$ Then, $P_x + P_y + P_z = 3P$

$$P = \frac{P_x+P_y+P_z}{3} = \frac{m}{3V}\sum\left(\vec{v}_x^2+\vec{v}_y^2+\vec{v}_z^2\right) = \frac{m}{3V}\sum \vec{v}^2$$

Or

$$P = \frac{P_x+P_y+P_z}{3}\ P = \frac{Nm}{3V}\frac{\sum \vec{v}^2}{N}\ or\ P = \frac{1}{3}\left(\frac{Nm}{V}\right)\vec{v}^2$$

$$P = \frac{N}{N}\left(\frac{m}{3V}\sum \vec{v}^2\right) = \frac{Nm}{3V}\frac{\sum \vec{v}^2}{N}$$

Let the mean square velocity of the molecules $\dfrac{\sum \vec{v}^2}{N} = v^2$

Then $P = \dfrac{Nm}{3V}v^2$ but Nm= mass of the gas M

$\therefore P = \dfrac{Mv^2}{3V} = \dfrac{1}{2}mv^2\left(\dfrac{2}{3V}\right)$ here $\dfrac{1}{2}mv^2$ =KE of the gas

Then $P = KE\left(\dfrac{2}{3V}\right)$ (or) $PV = \dfrac{2}{3}KE$

But PV=RT $\quad \therefore RT = \dfrac{2}{3}KE$

(or) $KE \propto T$

the average KE of a gas is directly proportional to absolute temperature of the gas

2. A refrigerator is to maintain eatables kept inside at 9^0C. If room temperature is 36^0C, calculate the coefficient of performance

A) The coefficient of performance of a refrigerator

$$\alpha = \frac{T_2}{T_1 - T_2}$$

Here T_1=273+36 = 309K, T_2=273+9=282 K

$$\therefore \alpha = \frac{282}{309-282} = \frac{282}{27} = 10.4$$

3. Find the external work done by the system in kcal, when 20 kcal of heat is supplied to the system the increase in its internal energy is 8400J. (J= 4200 J/kcal)

A) From the first law of thermodynamics,

$\Delta Q = \Delta U + \Delta w$

Given $\Delta U = 8400J = \dfrac{8400}{4200} = 2kcal, \Delta Q = 20kcal$

The external work done

$\Delta W = \Delta Q - \Delta U = 20 - 2 = 18cal$

4. Find the efficiency of a heat engine if the temperature of the source is 100^0C and sink is 27^0C

A) Formula: $\eta = 1 - \dfrac{T_2}{T_1}$

Given T_1=373K, T_2=300K

$$\eta = 1 - \frac{300}{373} = 1 - 0.8043 = 0.1957(or)\eta = 19.57\%$$